Dedication

To Dr. Ava Fajen

Who has been my partner, wife, and chief editor for over 25 years. I couldn't be more lucky.

About the Author

J Scott Christianson is a successful instructor and business owner with more than 23 years of experience in networking, videoconferencing technology, and project management. A Project Management Professional (PMP), Scott has worked hundreds of videoconferencing projects, from small to large. He currently serves as an Assistant Teaching Professor in the Trulaske College of Business at the University of Missouri and remains actively involved in videoconferencing technology and applications.

Scott also serves on the State Technical College of Missouri Board of Regents, currently serving as the board's Vice-President. He operated Kaleidoscope Videoconferencing in Columbia, MO for over eighteen years and holds a Master of Arts in Education and Human Development from the George Washington University. More about Scott can be found at christiansonjs.com.

Also by J Scott Christianson

Virtual Classrooms: Educational Opportunity through Two-Way Interactive Television, by Vicki M. Hobbs and J. Scott Christianson

Computer and Network Professional's Certification Guide, by J Scott Christianson and Ava Fajen.

Welcome

Do you want to make a difference in the world? Or make a difference in your life or your community? Then be a project manager!

Whether the project is an international marketing campaign for a non-profit, constructing a new building, setting up a new website, or creating an app, people are using project management to change our world every day.

In this text, I'll introduce you to the fundamentals of traditional project management techniques, as codified by standards/certification bodies such as the Project Management Insitute and International Project Management Association. My goal is to teach you new skills that you can build on as you develop your career in project management.

A Textbook for Me and You!

Having been a project manager for over a decade—and having taught hundreds of classes and workshops on project management—I wanted to find a textbook that would be:

- **Designed for a "flipped" classroom structure**. A textbook with short and concise readings with appropriate videos embedded. A student workbook for taking notes while reading so students are ready to work on exercises in class, instead of listening to a lecture that repeats, or tries to clarify, a complicated textbook.
- **Accessible** to my students, and not bogged down with academic language or irrelevant research. Something that would provide students with a good introduction to basic vocabulary and concepts without using a lot of technical language.
- **Granular,** so that each section would focus on one topic and just that topic. This way, instructors can assign just the sections or chapters they want and not be worried that students will get sidetracked with material that the instructor doesn't want to focus on in their course.
- **Focused** on the essentials of project management. There is a lot to learn in project management, but with a good understanding of the essentials, students can learn advanced concepts and the "exceptions to the rules" on their own.

After searching for such a book for years, and not ever being happy with the results (or the $280 plus price tags for students), I decided it would be easier to just write the book I wanted.

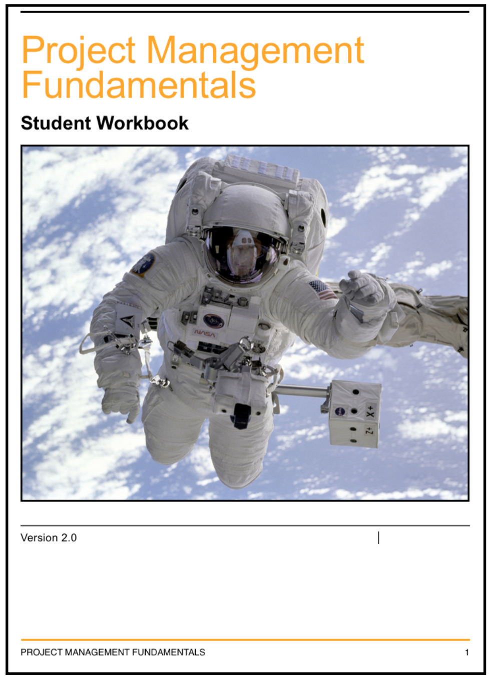
Version 0.5 of a Textbook?

This is an incomplete textbook. The sections that are included are complete, awesome and ready to be put to use by instructors and students. However, more chapters are required to have a completed text on Project Management. But what chapters or new sections would be most useful?

By releasing Project Management Fundamental at the 0.5 stage instructors and students can provide feedback to guide the development of the text and companion materials. Just like a new software app, I'll release updated versions of the text with new materials and features added as the book develops to a more complete, 1.0 version. I think this will lead to a much better text that represents what project management students and instructors really need in an up-to-date text.

You can view the current roadmap for the development of this text and provide your feedback online at: http://pmf.education/roadmap/. **Any and all feedback is welcome.** And you are interested in contributing a chapter or section, please contact me and we can discuss the possibilities in more detail.

Student Workbook



Students learn better when they take notes by hand. So as a companion, I have created a student workbook for taking notes, completing exercises, and testing one's knowledge with quizzes. Students can download the student workbook as a .pdf file and print out for spiral binding at your local copy shop or placement in a three-ring binder. (Answers to quizzes and exercises are provided.)

The student workbook also includes **MS Project Lab Exercises with video tutorials.** Download the latest from: http://pmf.education/download/

Instructor Resources

Resources for instructors can be found the pmf.education instructor resource blog (specifically at: http://pmf.education/intr_res/). In order to access these resources, you will have to register as an instructor at the site (approval take 24-48 hours).

Other Resources

1. The slides decks from the videos used in this text are freely available for download on speaker deck (https://speakerdeck.com/jscottmo).
2. This text can be obtained in several formats (ibooks, kindle, .pdf). Please see http://pmf.education/download/ for details.
3. All embedded and linked videos can be found at: https://www.pmf.education/videos/

Closed Captioning for Videos

The videos that are embedding in this textbook do not have closed captioning. However, under each video is a link to the video's location on YouTube where the viewer can turn on closed accurate captioning (hand-edited, not computer-generated).

Proofreaders and Advice Givers

Dr. **Ava Fajen** edited every chapter of the text and student workbook providing excellent feedback on making the text accessible for beginning project managers.

Dr. **Michael O'Doherty**, reviewed and provided feedback on the Project Selection chapter.

Jonathan Sessions, **Chris Sanders,** and **David Overfelt** all provided advice and help with developing this unique approach to textbook construction!

Images

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Formulas

I relied on this great website to help me with the Latex code for the formulas presented in this book: https://www.codecogs.com/latex/eqneditor.php

Rewards

Since I am self-publishing this textbook, there are not hordes of editors and proofreaders looking over my shoulder. That is great for getting material out the door quickly but not so good for having a textbook with zero errors. While I have had several people proofread this work and the companion guide, there might still be an error here or there. As a result, I am offering a reward those who submits a correction, or even an awesome suggestion, that I use in this book.

Rewards are decided by me and may include:

- Shout out on social media channels and/or website.
- Amazon gift certificate.
- Cute stuffed "Truman the Tiger" (our mascot at Mizzou)
- A box of hand-made gag gifts
- Or any number of other amazing things

Contact

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Chapter 1

Project Management Defined

Chapter 1 Overview

Projects are managed differently than other company or organizational operations. It is important to start our study of project management with some definitions and concepts from the field of project management. The three sections in this chapter will provide you with a good overview of the project management field, the ways that project managers approach projects, and the types of tools that are used to manage projects.

The first section will orient you to the field of project management at a high level, covering:

- Project Definition
- Operations vs. Projects
- Traditional Project Management
- Agile Project Management
- Project Scope Triangle
- Project Management Priority Matrix
- Program Management
- Project Management Office
- Project Portfolio Management

Projects have a defined life cycle with a start and an ending. In addition, there are many different processes that can used at various stages to effectively plan and manage the execution of a project. The second section in this chapter discusses the stages a project goes through from its beginning to end (the project lifecycle) and the processes used to manage projects through these stages.

The final section of this chapter introduces you to the main project management standards body in North America: Project Management Institute or PMI. PMI offers several certifications in Project Management and we'll take a look at two of the most applicable certifications for project managers: The Certified Associate in Project Management (CAPM) and the Project Management Professional (PMP).

Learning Objectives:

- Be able to define the characteristics that define a project.
- Understand the difference between traditional and Agile project management.
- Be able to explain how a project priority matrix is used.
- Understand how program management differs from project management.
- Understand the functions of a Project Management Office and Project Portfolio Management.
- Be able to explain the difference between a Project Lifecycle and the PMI Project Processes.
- Understand the basic requirements for the CAPM and PMP certifications.

Section 1

Project Definitions

Project Definition

The term “project” is used several ways in popular culture, from describing everyday tasks (planting a garden, hanging a picture, running errands) to large scale enterprises (building a house, constructing a new highway). However, when professional project managers talk about projects, they use a narrower definition.

Let's start out with the six defining characteristics of a project. Just about every book, organization, or standards body in the project management field agrees that a project:

1. is a temporary endeavor, with a defined start and end.
2. has a specific objective.
3. has customers or stakeholders.
4. has constraints, such as time, cost and scope.
5. has measures for success.
6. includes some amount of uncertainty.

Watch the video on **What is a Project** for more information on how these six aspects help define what a project is and is not.

Video 1.1 What is a Project

Watch this short video to learn what makes a project a project! Use the notetaker in the PMF Student Companion Guide to take notes. You can watch this video at: http://pmf.video/video1

What is the PMI Definition of a Project?

A project is a temporary endeavor undertaken to create a unique product, service, or result.

—Section 1.2 , page 2 from the Fifth Edition of the PMBOK Guide.

Operations vs. Projects

Projects are different from ongoing operations, even though some techniques (such as network diagramming) overlap. Project management addresses temporary endeavors, while operations management focuses on improving ongoing operations. For example, constructing a new factory is a project, while producing bicycle tires in that factory is an operation.

This textbook concentrates on traditional project management techniques. Adaptations related to Agile project management, which is often used for software development, are mentioned along the way, but Agile is not a main topic in this text. It is discussed in this first chapter so students will have an understanding of basic Agile concepts.

Traditional Project Management

While project management can be traced back to the building of the Great Pyramids in Egypt, it was really in the post-WW2 industrial boom of the 1950s that project managers started to develop the tools and techniques used in modern project management. These tools were used to complete large industrial and military projects, where the scope of work (what we need to accomplish in a project) was well defined. For example, the scope of what we have to do can be planned out well when we are constructing an apartment building, making a nuclear submarine missile, building an oil refinery, etc.

These traditional techniques have been elaborated and standardized by organizations such as the Project Management Institute (PMI) in the US and The International Project Management Association (headquartered in Switzerland) and AXELOS (the organization behind the PRINCE2 certification used in Great Britain).

These traditional techniques were also adapted to software development. Techniques such as waterfall, and function point analysis were advanced as effective ways to manage software development projects. However, as the world of software development changed—from large, time-consuming projects that were loaded on mainframe computers to fast-moving, fast-changing, internet-based applications—many programmers found waterfall and similar methods to be limiting. These techniques lacked flexibility and were inadequate to deal with a rapidly changing, competitive landscape. As a result, a "revolution" of sorts was mounted and out of that revolution came several so-called Agile project management methods.

What is the PMI Definition of Project Management?

Project management is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements.

—Section 1.3 , page 4 from the Fifth Edition of the PMBOK Guide.

Agile Project Management

Agile is broad term for project management techniques that are iterative in nature. Rather than trying to develop all aspects of a project or software application and then presenting that result to the customer after a long development cycle (6 to 24 months), Agile techniques use short development cycles in which features of high value are developed first and a working product/software can be reviewed and tested at the end of the cycle (20-40 days).

This allows the customer to verify that the features are being developed as they want, and to suggest improvements. It also offers the customer the opportunity to release the product or software earlier than originally planned if the version presented at the end of a cycle is deemed good enough. This is one of the many reasons Agile is favored for software development. With Agile products can be brought to market quickly and then continuously improved with subsequent updates.

For many years, some “traditional” and Agile project managers viewed each other with a certain amount of skepticism about the value of each other’s methods. However, in recent years project managers have seen the value of the techniques used in both of these two “camps” of project management. As a result, it is not unusual to see the design of a building using Agile techniques, and software development projects conducting a traditional risk analysis. Picasso is credited with saying “Good artists borrow, great artists steal.” The same holds true for project managers. The great ones steal ideas that work from wherever they find them.

Figure 1.1 Agile projects are iterative

Agile project management usually uses short development cycles that produce working versions of the software with each revision (albeit without all the features). This allows the customer to provide continuous feedback and release the product as soon as possible.

Agile Methods

There are many different types of Agile project management methods. Here is a short list of some popular methods with links for more information:

- Extreme programming (XP)
- Lean software development
- Kanban
- Scrum

The Manifesto for Agile Software Development

We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:

Individuals and interactions over processes and tools

Working software over comprehensive documentation

Customer collaboration over contract negotiation

Responding to change over following a plan

That is, while there is value in the items on the right, we value the items on the left more.

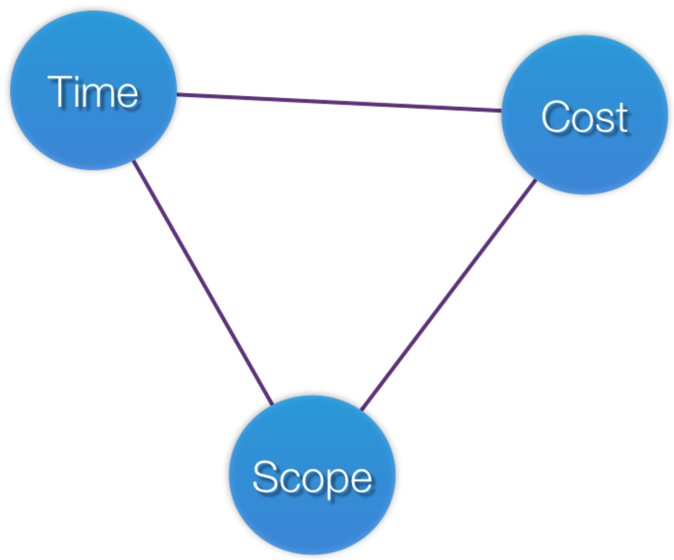
—from http://www.agilemanifesto.org/

Project Scope Triangle

Now, returning to our introduction to traditional project management, let's define some basic terms and concepts. First that all projects have constraints. The primary constrains on any project are:

- **Time**: the amount of time we have to complete our project.
- **Cost**: the budget for our project.
- **Scope**: the features that our end product will have.

Figure 1.2 The Scope Triangle

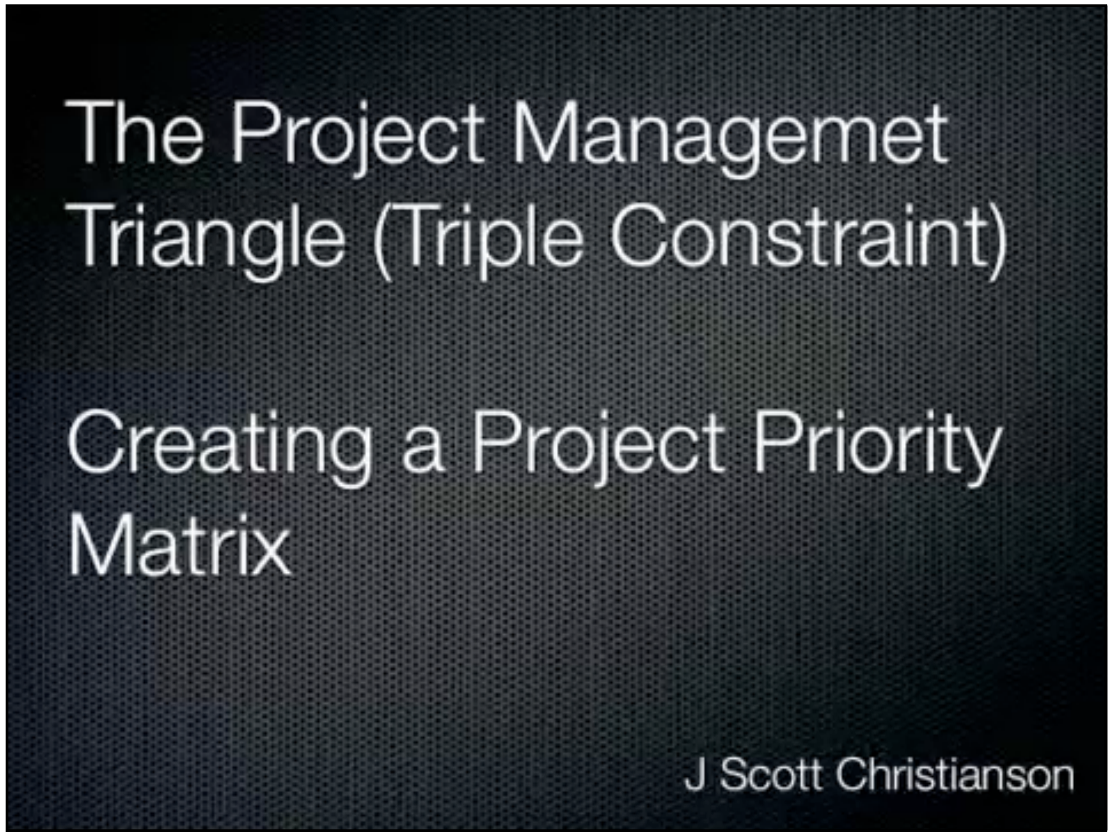


The Scope Triangle or "Triple Constraint" can represented in a number of different ways. Regardless of how it is presented, understand that we have to make trade-offs between these constraints as our project moves forward.

PMI and other organizations have since added **risk**, **quality**, and **resources** to the list of constraints. Regardless of how project constraints are presented, each project constraint interacts with the others in ways that force us to consider trade-offs. For example, if we are going to hold fast to a deadline for finishing a project, we may need the flexibility to hire more resources to get the job done on time.

Project Management Priority Matrix

Video 1.2 The Scope Triangle and the Project Priority Matrix



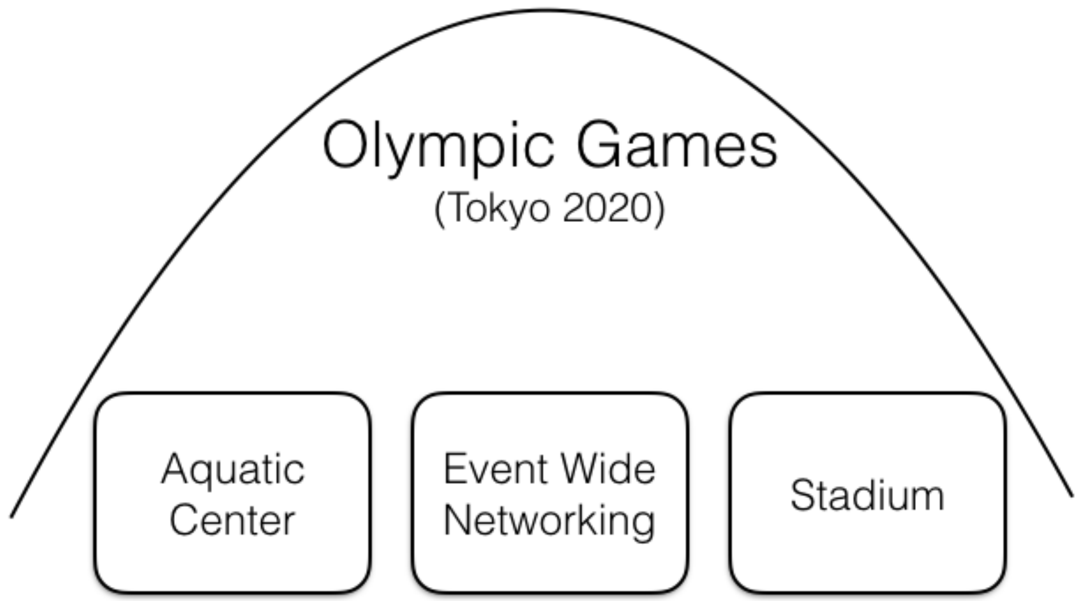
Watch this short video to learn more about the triple constraint and how a Project Priority Matrix can be used to communicate trade-offs between time, cost and scope. Use the notetaker in the PMF Student Companion Guide to take notes. You can watch this video at: http://pmf.video/video2

In order to make sure that all stakeholders are in agreement (or at least have a discussion) about the priorities of a project, a Project Priority Matrix can be used to make sure the trade-offs between Time, Scope, and Cost are clear and that the project manager has some guidance on the project priorities. Watch the video about the **Scope Triangle and the Project Priority Matrix** to learn more about how we can constrain, accept, or enhance these aspects of our project.

Program Management

A program is a set of coordinated projects. Program management is the process of managing all these coordinated projects.

Figure 1.3 Programs and Projects



A program is a set of related projects. Program managers work with the various project managers to balance resources across all project to make sure that deadlines are met.

Program managers work with the project managers on the various projects that make up the program, in order to balance resources, risk and scope.

My favorite example of a program is when a country hosts the Olympic games. Hosting the Olympics is a program, with many different projects that have to fit together and be ready by a very specific deadline: constructing stadiums, and aquatic centers, creating marketing campaigns, installing new networks and power connections for media, etc. By coordinating all these projects, program managers can make sure that all is ready in time for the opening ceremonies.

Project Management Office

Organizations often have many project managers working on multiple projects, which may or may not be part of a coordinated program. In order to support these project managers, a Project Management Office (or PMO) is often developed to provide a central place for development of project management best practices, for collection of lessons learned, and to assist with Project Portfolio Management (PPM). Some PMOs will also provide support for project managers by conducting analyses (for example, Monte Carlo risk analysis) and assisting with time and cost estimates, etc.

Project Portfolio Management

Almost every organization has more ideas for possible projects than they could ever hope to complete. Each one of these project ideas might be good and might result in a successful project that would move the organization forward. However, an organization will simply not have the resources or time to complete all possible projects.

As a result, organizations will typically keep a list or **portfolio** of possible projects, and review this portfolio periodically to see if this is the right time to pursue a particular project. (For details on project selection, see the Project Selection Chapter.)

Project Portfolio Management (PPM) is the method used to judge proposed projects based an organization’s strategic goals.

Section 2

Project Management Life cycles and Processes

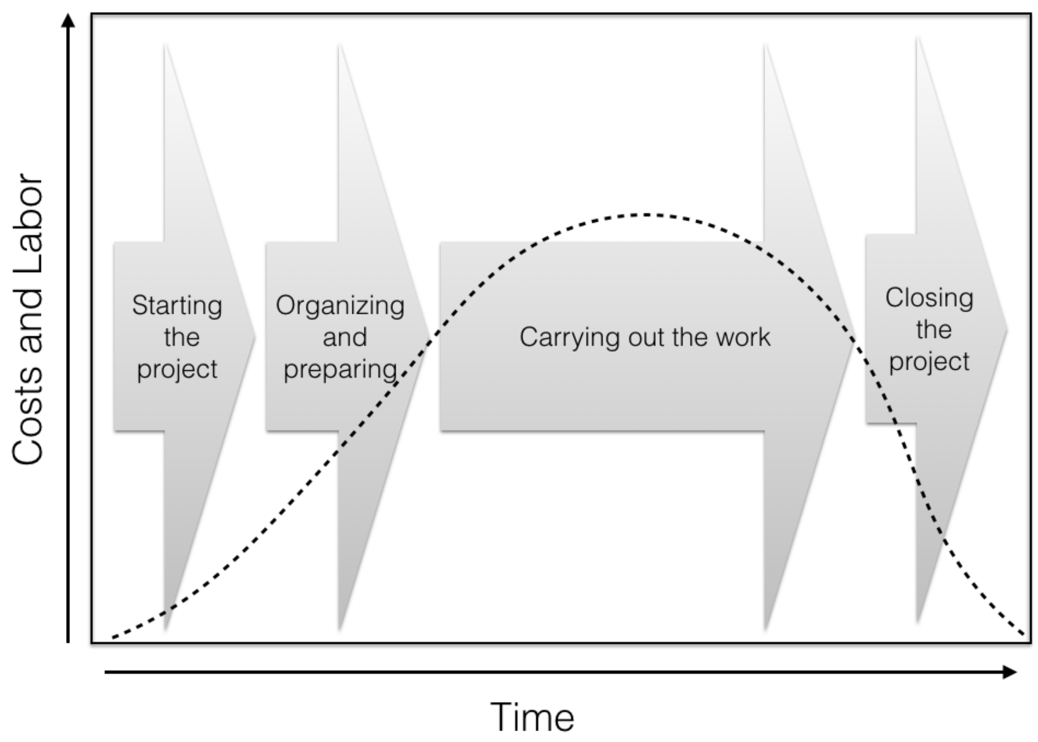
Project management life cycles represent the different stages that a project goes through, from conception to its final completion. Different industries represent project life cycles in ways that make sense for their area of expertise. Regardless of the life cycle, at each stage of our project there are a number of processes that we will use to manage the project.

PMI and Project Management Life cycles.

PMI provides a generic project life cycle—shown in the figure below—in which the project moves from **starting** to **organizing and preparing** to **carrying out the project work** and finally to **closing the project**.

This is just one example of a project management life cycle. The figures on to the right shows other examples from various industries/methodologies.

Figure 1.4 PMI's Generic Project Life Cycle



As our project progresses, the amount of work and costs (shown by dashed line) increase and then drop off as our project ends.

Figure 1.5 Construction Project Life Cycle

Figure 1.6 Marketing Project Life Cycle

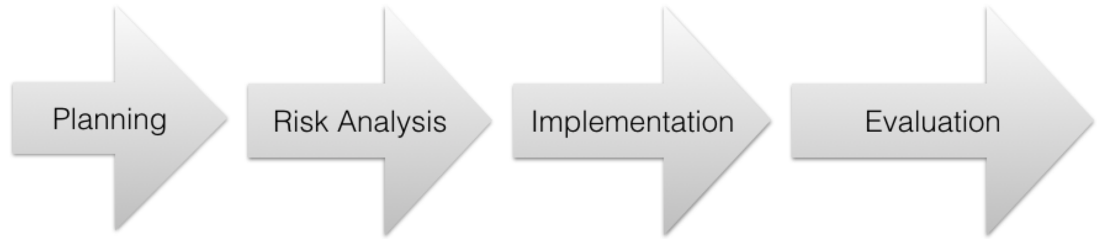
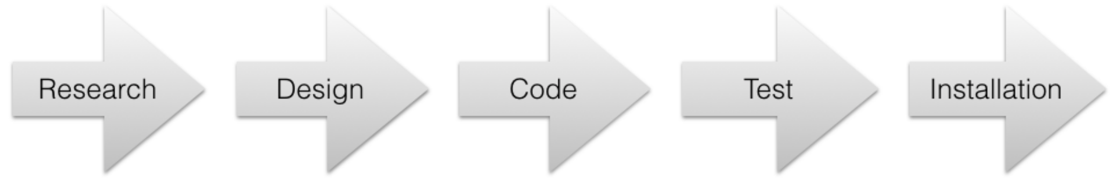


Figure 1.7 Software Project Life Cycle



When do Projects Fail?

When a project fails, we tend to notice that failure as the project is ending; for example, when customers refuse to accept the project, when testing shows that our project product does not work as designed, or when budgets are overspent, when deadlines are missed for completion. However, most project managers would say that project failure really occurs in the beginning stages of a project and is the result of poor planning and design. That is why the project management field so heavily emphasizes planning processes: **good planning pays off!**

This is not to say that projects will not have problems, but if proper planning has occurred there will be mechanisms in place for the project team to quickly address any problems and get the project back on track.

Video 1.3 A lack of risk management planning led to one of the most famous bridge collapses.

Not all projects fail as spectacularly as the Tacoma Narrow Bridge. You can watch this video at: http://pmf.video/video3

The five processes

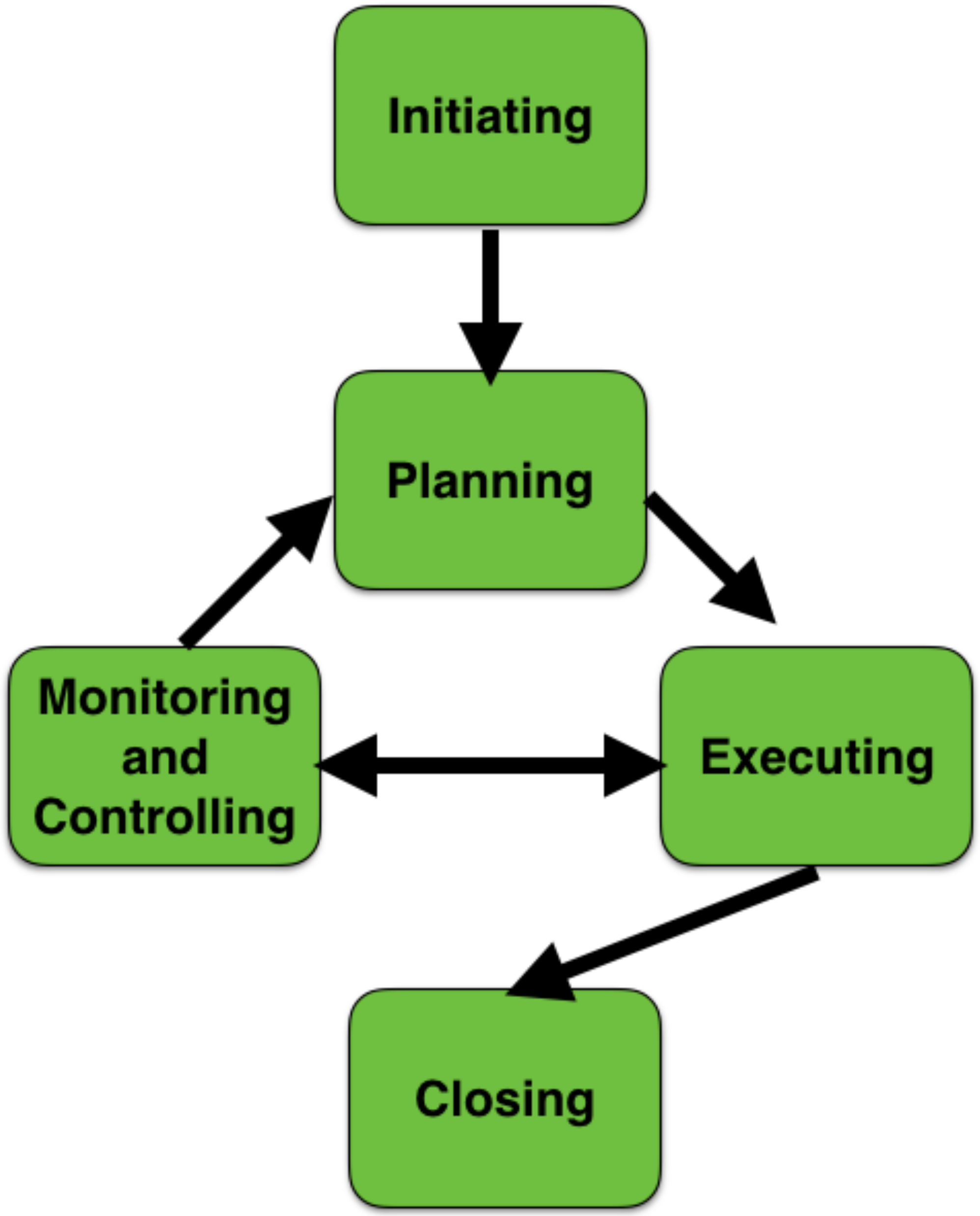
PMI has identified five main groups of processes that are used in project management. There are over forty individual processes that project managers may use within these groups.

Beginning project managers will confuse these process groups with a project management lifecycle; for good reason, most of the initiation and planning processes are the focus at the start of a project, and the closing processes can be a be focus at the close of the project. However, these process groups are not the same as a lifecycle and may be used many times in the management of a project. That is to say that not all planning processes happen at the beginning of the project and not all closing processes happen at the end. These five processes are how we manage the project during its lifecycle.

In addition, we may continuously repeat these processes as we are managing various aspects of our project. For example, while work on our project is underway, we may be continually executing our risk management plan, monitoring and controlling risks, and continuing our planning process to deal with newly identified risks within our project. This may go on for several months or years, depending on the complexity of our project.

If you are familiar with the Plan, Do, Check, Act cycle that was popularized by Dr. Edwards Deming, then you will recognize strong similarities to how PMI regards these five processes.

Figure 1.8 Project Management processes



While our project is being performed, we will be continuing to monitor and control that work, and plan for changes, or new risks in our project.

Process inputs and outputs

PMI describes the inputs needed for each process, tools used in the process, and the resulting deliverables once the process is complete. For example the Develop Project Charter process has the following inputs, tools and deliverables:

Develop Project Charter Inputs

- Enterprise Environmental Factors (for example, organizational structure and culture).
- Project Contract (if applicable).
- Project Statement of Work.
- Organizational Process Assets (lessons learned from other projects, etc.)

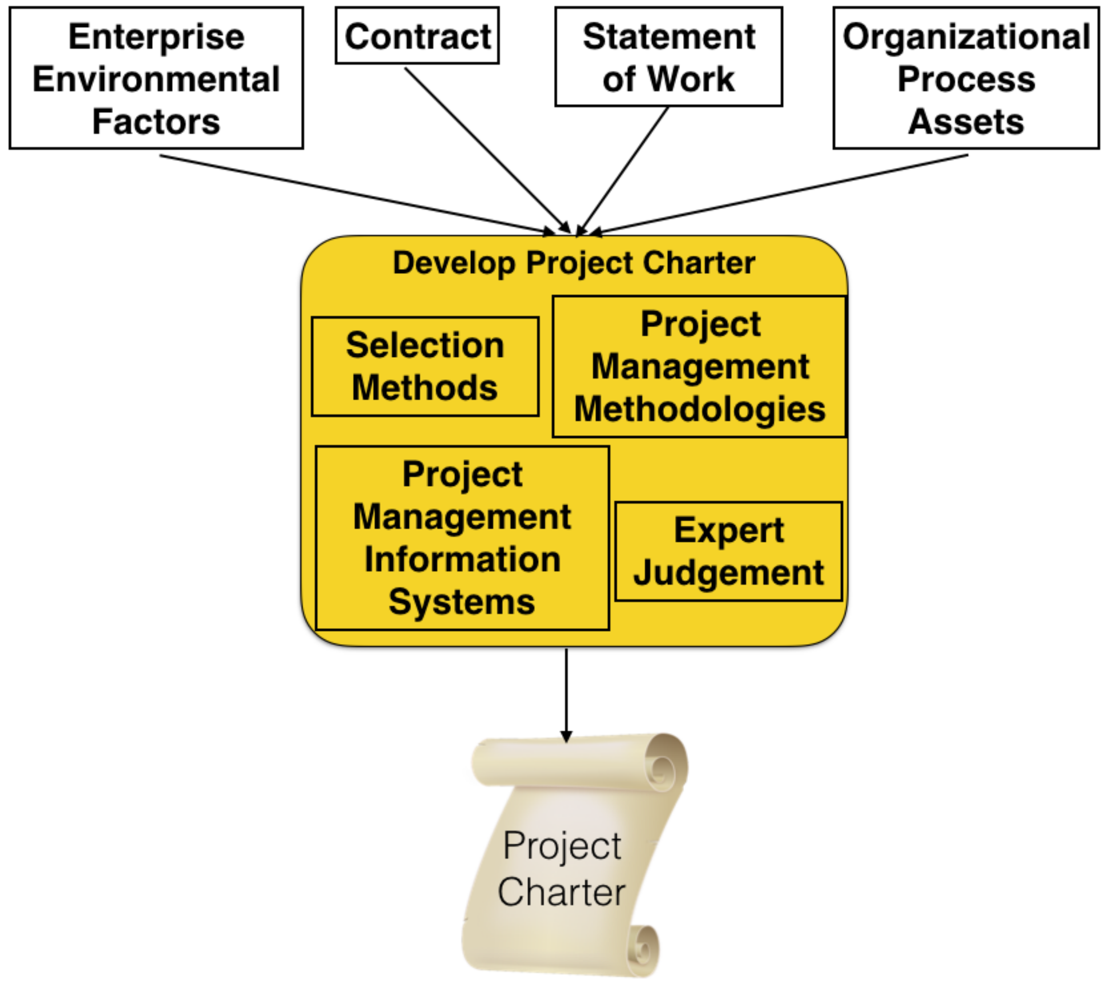
Develop Project Charter Tools

- Project Management Information Systems
- Project Management Methodologies (PMBOK standards for example).
- Project Selection Methods (we'll look at those in a later chapter).
- Expert Judgement (the experience of project managers).

Develop Project Charter Deliverables

- Project Charter.

Figure 1.9 Processes have Inputs, Tools and Deliverables.



Each process has a number of inputs that are used to develop the final output (or deliverable) of the process. In addition, the output of one process can be used as the input in another process. For example, the deliverable "Project Charter" is used as an input in the "Plan Scope Management" process.

Studying the PMBOK Processes

Many students who want to pass the PMI certification exams will try to memorize the inputs for each process, the tools for each process, and the deliverables created by each process. Starting out with this approach typically leads to failure on the exam. It is better to learn about the inputs, tools, and deliverables without trying to map them to specific processes. Once you understand and have mastered the tools the project managers use, it will be very clear what process these tools belong to, what inputs are needed by the tools, but they produce, and how the processes are ordered.

For now, just review the process groups in the rest of this section. Then, when you are done with this your study of project management, come back and review these process groups again, and you will see that the grouping and ordering of the progresses makes perfect sense.

Initiating Processes

Initiating processes help us produce a framework for our project and obtain the authorization (in the Project Charter) for the project manager to move forward with the project. By identifying the Stakeholders for our project, we are able to know who needs to be involved and informed about our project and its objectives. Initiating Processes include:

- Develop Project Charter.
- Identify Stakeholders.

Planning Processes

The majority of the processes are in the planning process group. These processes are the most important for the success of our project, and this book will concentrate on these processes. Planning Processes include:

- Develop Project Management Plan
- Plan Scope Management
- Collect Requirements
- Define Scope
- Create WBS
- Plan Schedule Management
- Define Activities

- Sequence Activities
- Estimate Activity Resources
- Estimate Activity Durations
- Develop Schedule
- Plan Cost Management
- Estimate Costs
- Determine Budget
- Plan Quality Management
- Plan Human Resource Management
- Plan Communications Management
- Plan Risk Management
- Identify Risks
- Perform Qualitative Risk Analysis
- Perform Quantitative Risk Analysis
- Plan Risk Responses
- Plan Procurement Management
- Plan Stakeholder Management

Executing Processes

Executing Processes focus on the completion of actives and work packages. Executing Processes include:

- Direct and Manage Project Work
- Perform Quality Assurance
- Acquire Project Team
- Develop Project Team
- Manage Project Team
- Manage Communications
- Conduct Procurements
- Manage Stakeholder Engagement

Monitoring and Controlling Processes

The Monitoring and Controlling Processes focus on understanding how well our project is proceeding; how that progress compares with our plan; and controlling scope, schedule, costs, quality, communications and risks.

Monitoring and Controlling Processes include:

- Monitor and Control Project Work
- Perform Integrated Change Control
- Validate Scope

- Control Scope
- Control Schedule
- Control Costs
- Control Quality
- Control Communications
- Control Risks

Closing Processes

At the end of a phase of our project, or the entire project, we must get final approval from the customer, archive our records from the project, compile the lessons learned, and pay any outstanding bills. These and several other actives make up the closing processes. Closing Processes Include:

- Close Project or Phase
- Close Procurements

Section 3

Project Management Standards and Certifications

As a science, project management continues to evolve and change. There are several organizations around the world who work to develop standards and best practices for project management. In North America, the main standards body is the Project Management Institute, or PMI. This section takes a look PMI standards and certifications.

The Science of Project Management

Project management has been around for centuries if not millennium. From the building of the pyramids to the construction of the great buildings of 19th century London, people have developed ways to breakdown large projects into smaller more manageable chunks, scheduled the work and obtain the materials needed for the project. During that time, many tools were developed to manage projects. However, it was not until the large, highly complex defense projects undertaken by the United States during the 1950s drove a push for a more scientific and data-driven, management approach to projects and was the beginning of the science of modern day project management.

Figure 1.11 Henry Laurence Gantt (1861 – 1919)

Gantt was mechanical engineer who is best known for developing the Gantt chart in the 1910s. These charts allowed managers to quickly compare the planned schedule to the actual work that was completed. Gantt's ideas were the basis of Program Evaluation and Review Technique (PERT) that was developed in the 1950s.

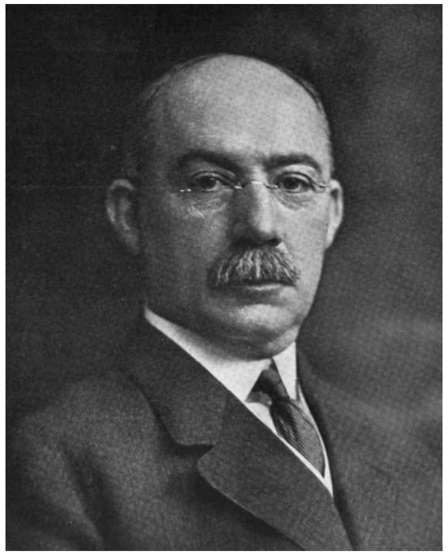
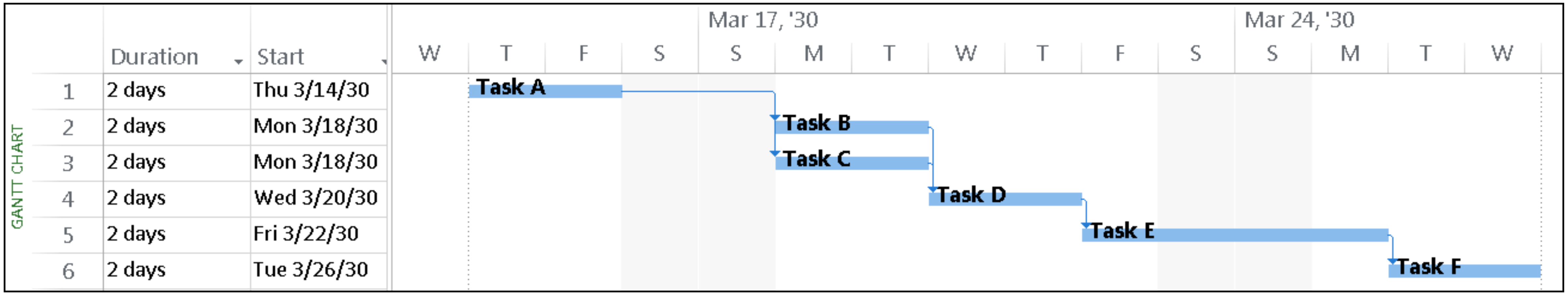


Figure 1.10 A Gantt chart.



A Gantt chart is a simple, but effective way to display a project plan, and compare our progress to that plan.

Project Management Institute

The Project Management Institute started in 1969 as an effort to share best practices; those Today, it is a It is a non-for-profit organization with over 500,000 members. PMI has chapters throughout the world, each offered additional benefits in the form of professional development and networking opportunities.

What is the mission of PMI?

At PMI, our primary goal is to advance the practice, science and profession of project management throughout the world in a conscientious and proactive manner so that organizations everywhere will embrace, value and utilize project management and then attribute their successes to it.

—from PMI.org

Project Management Body of Knowledge.

PMI has codified the standards for project management in the Project Management Body of Knowledge (PMBOK) guide. The PMBOK is best used as a reference guide, it is not recommend for cover to cover reading. The PMBOK Guide has been recognized as a Standard by the American National Standards Institute (ANSI) and the Institute of Electrical and Electronics Engineers (IEEE). The PMBOK guide is organized into nine knowledge domains:

- Project Integration Management
- Project Scope Management
- Project Time Management
- Project Cost Management
- Project Quality Management
- Project Human Resource Management
- Project Communications Management
- Project Risk Management
- Project Procurement Management
- Project Stakeholder Management

Project Management Certifications

PMI offered several project management certifications. These credentials demonstrate the holders mastery of the concepts in the PMBOK and experience in the field.

Certified Associate in Project Management (CAPM)

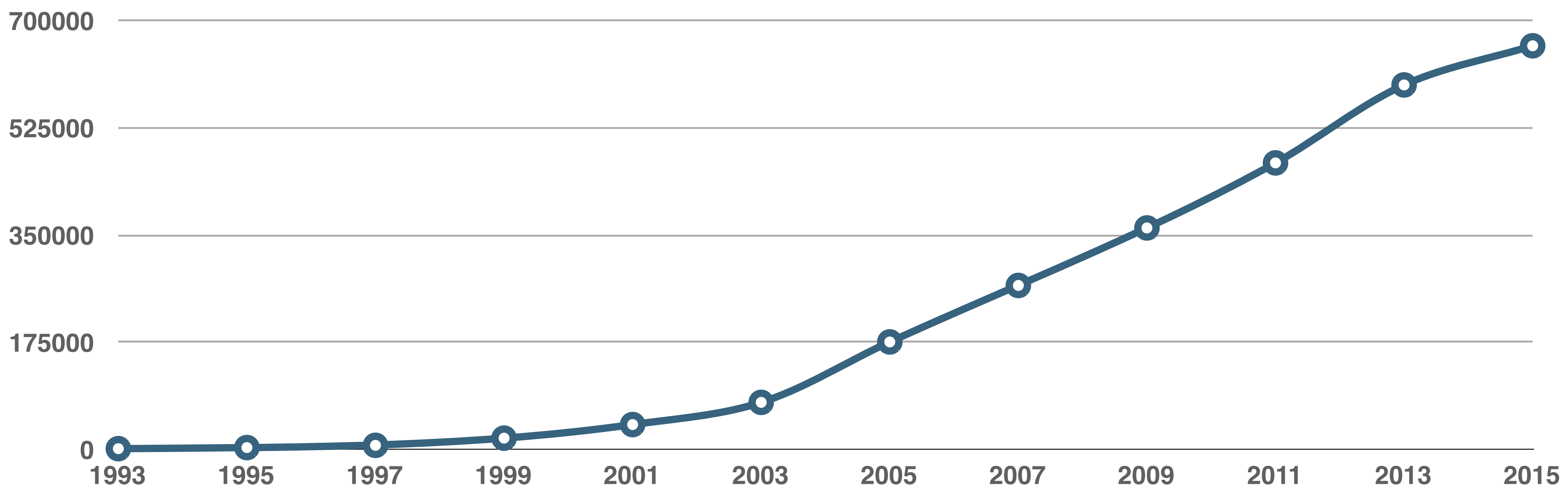
The CAPM is an entry level certificate that is an excellent way for students to show that they understand how and will be an effective project team member.

The CAPM certification requirement are listed in the Table on the next page. Please note that the 23 hours of project management education is not credit hours, but contact hours. Most students taking a semester long project management course will easily meet this education requirement.

Project Management Professional (PMP)

The PMP is the most popular of the certifications that PMI offers and requires a significant amount of experience managing projects before taking the certification exam. This experience has to be documented; Information for each each of the projects on which a potential PMP worked must be provided including the role they played in the project and contact information for third party verification. This part of the application is subject to auditing by PMI. PMI randomly audits applications to take the PMP exam, as well as a small number of existing PMPs. This do this to make

Figure 1.12 Growth in PMP certifications



sure that they requirements are being met and the credential reflects a high level of expertise in the project management field.

The number of PMP’s continues to increase each year (see the figure below, and PMP’s continue to be in demand as companies try to develop better ways to manage their projects. (one area of substantial growth in the past years in demand for PMPs is in the value of a PMP is health informatics).

Each year PMI releases a salary survey of PMI credential holders, which shows that those project managers who have gone through the process of certification are compensated better than their non-certified colleagues.

Both certifications require a rigorous test. For more details visit PMI’s web site at: http://www.pmi.org/certification.aspx

Sidebar 1.1 Resources for CAPM and PMP Study

There are several excellent books and web sites to help people prepare for the CAPM and PMP exams. Below are just a couple recommended resources.

Books

- PMP Exam Prep, Eighth Edition - Rita's Course in a Book for Passing the PMP Exam Eighth Edition by Rita Mulcahy.
- Head First PMP 3rd Edition by Jennifer Greene and Andrew Stellman.
- PMP: Project Management Professional Exam Study Guide 7th Edition by Kim Heldman

Websites

- PMP subgroup on Reddit: https://www.reddit.com/r/pmp/

Table 1.1 Requirement for the CAPM and PMP exams.

	CAPM	PMP
Full Name	Certified Associate in Project Management	Project Management Professional
Project Role	Contributes to Project Team	Leads and Directs Project Teams
Eligibility Requirements	A secondary degree (high school diploma or the global equivalent) AND (At least 1,500 hours of project experience OR 23 hours of project management education by the time you sit for the exam.)	A secondary degree (high school diploma or the global equivalent) with at least five years of project management experience, with 7,500 hours leading and directing projects and 35 hours of project management education. OR A four-year degree (bachelor's degree or the global equivalent) and at least three years of project management experience, with 4,500 hours leading and directing projects and 35 hours of project management education.
Steps to Obtaining Credential	Application Process and Multiple-Choice Exam	Application Process and Multiple-Choice Exam
Exam Information	3 hours, 150 questions	4 hours, 200 questions
Fees	\$225 PMI Member \$300 non-Member	\$405 PMI Member \$555 non-Member
Credential Maintenance	5-years, re-exam	Every 3 years, must earn 60 Professional Development Units

Chapter 2

Project Management Roles

Chapter 2 Overview

In many ways, managing projects is really about managing relationships with people. In this chapter, we will explore three main categories of people who will influence the success of our project: the project manager, the project team, and the project stakeholders.

The first section explores the role of the project manager. The project manager (or PM) is the person who is responsible for

- Communicating with stakeholders
- Generating project planning documents
- Assembling, motivating and managing the project team.
- Monitoring and reporting on project progress.

The second section explores how teams develop and how a project manager can nurture and help build high-performance teams. This section will look at some of the stages that teams go through during the life of a project, including:

- Forming
- Storming
- Norming
- Performing
- Adjourning

The last section explores the importance of identifying and managing project stakeholders. Stakeholders are defined as anyone with an interest in a particular project, including:

- Internal Stakeholders
  - Top Management
  - Functional Managers
  - Project Team Members
- External Stakeholders
  - Clients
  - Competitors
  - Suppliers
  - Regulatory Bodies
  - Government
  - Citizen Groups

Learning Objectives:

- Understand the characteristics that make a good project manager.
- Explain Theory X and Y as it relates to project managers
- Understand the basic needs of our team members.

- Explain the stages that a project team goes through and be able to identify the role that a project manager should try to play during each stage.
- Understand the importance of stakeholder identification and management.
- Understand how a Stakeholder Register and Stakeholder Matrix are used.

Section 1

The Project Manager

Just like the term “project,” the term “project manager” can used very loosely in common parlance. PMI recognizes that while the authority of project managers varies greatly from one organization to another, true project managers will have the responsibility of the planning, execution, and closing of a project.

The Role of the Project Manager

The project manager is involved in a project throughout its life cycle. The PM develops the project plans, makes sure those plans are executed, with appropriate changes as needed, and turns over the project when it is complete.

Being a project manager can be extremely rewarding but comes with its set of challenges. A project manager may have responsibility for a project's success but often does not have full authority over the resources required to complete the project successfully. This is one reason why having great interpersonal skills is important for project managers: they may have to negotiate for project resources from upper management or functional managers within the organization.

Being a great communicator, and working well with a variety of personalities, are key skills for a project manager (skills that can be developed and improved in anyone, by the way). A project manager will use these skills not just with upper management, but also with other stakeholders and the project team. One of the main responsibilities of a PM is motivating and building project teams. How a PM behave in this role will depend on how they view the motivation of their team members.

The Project Manager as Team Leader

In the late 1960s Douglas McGregor put forth two models to explain how managers view the motivation of their employees and team members: **Theory X and Theory Y**. These theories describe two very different viewpoints on how employees act and how they are motivated.

Project managers who are aligned with Theory X will think that employees generally try to avoid work when they can, don't take responsibility for getting work done, and may be incompetent or incapable of performing good quality work. These project managers will try to micromanage their employees. Unfortunately, this often leads to a self-fulfilling prophecy, whereby employees become unmotivated because they are not trusted.

Sidebar 2.1 Characteristics of an effective project manager.

1. Great communication and interpersonal skills.
2. Knowledge of project management processes.
3. Supports his or her team members.
4. Welcomes new ideas,
5. Has a tolerance for ambiguity.
6. Creative problem solver.

Think about your own experience. Have you ever been given a simple task to perform, but the person who asked you to do it keep telling you how to do it or wanting constant updates on progress? If so, how did that affect your motivation?

Project Managers aligned with Theory Y believe that team members put forth their best efforts without being closely managed, will ask questions without prompting, have a desire to meet their goals and will take responsibility for their work. These project managers will trust their team and not try to micromanage.

In general, a project manager with a Theory Y mindset will be able to establish trust with team members and lead them from the formation of a team to becoming a high performing team.

Stephen M.R. Covey has written an excellent book titled The Speed of Trust. In his book, he talks about how easy it is to get work done with a colleague or partner you trust, and how difficult it can be to work with someone that you don't trust. If there is someone on the team who cannot be trusted, it is the project manager's duty to get rid of them quickly. Project managers who can build trust between team members early on in the process will have a team that can work well together when challenges arise.

Section 2

The Project Team

The project team works with the project manager to develop the project management plans, schedule the work of the project, acquire the needed resources, monitor project progress and see the project through to its successful completion. Team members may be devoted solely to working on the management aspects of a project, or may also be performing the work of the project. How well the project team works together will determine the success or failure of a project.

Team Member Motivation

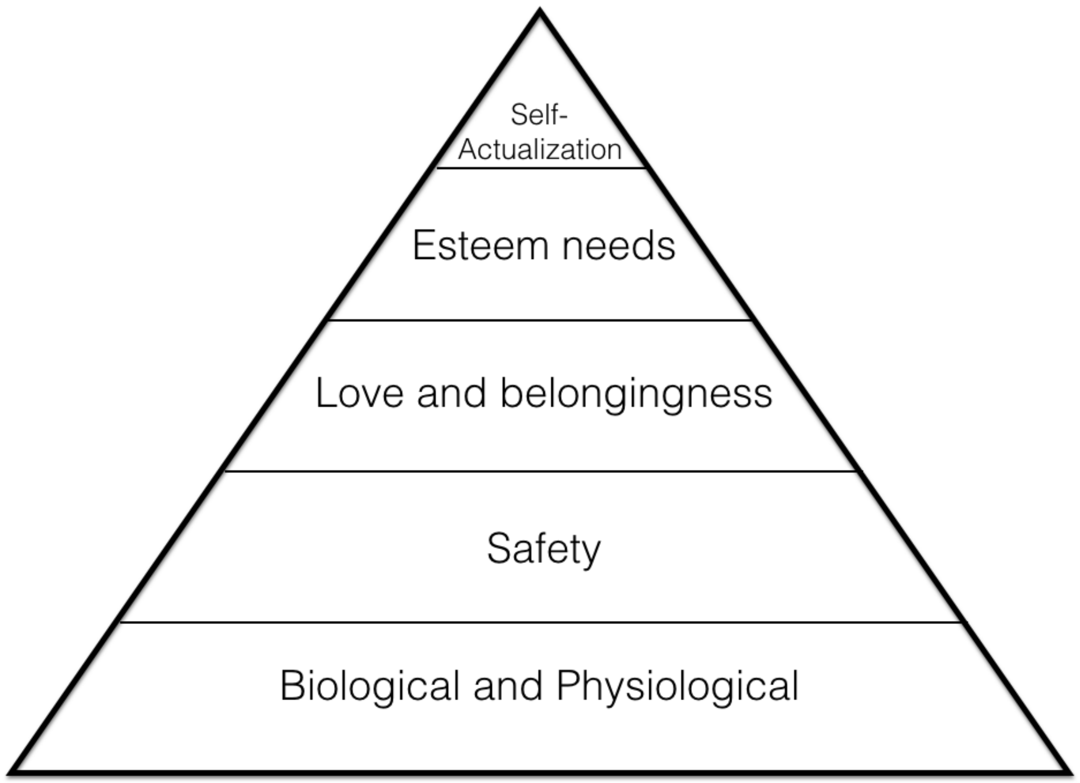
The last section mentioned McGregor's Theory X and Theory Y in regard to how project managers may view the motivation of team members. Let's now take a look at what motivates individuals, teams, and organizations.

Basic Needs: Maslow's Hierarchy of Needs

Abraham Maslow provided a model to understand basic human needs which is usually represented as a pyramid (see Figure 2.1). Each need builds on the others: A person's esteem needs are not that important if they are struggling with meeting the biological need to eat. Here are each of the levels in Maslow's hierarchy:

1. **Biological and Physiological:** What a person needs to survive, such as food, water, and shelter.
2. **Safety:** The need to be safe in your person, have financial security, and protection against accidents and illness.
3. **Love and Belongingness:** The need to be loved by one's family and community.
4. **Esteem:** The need to be respected and valued by others.
5. **Self-Actualization:** At the top of the pyramid is the desire to becoming the best self that you can: to become the best artist, parent, or project manager you can become.

Figure 2.1 Maslow's Hierarchy of Needs



For project managers, this model is useful in several ways. It explains why team members who have problems with their health, family relations or other "lower" needs, will have a problem performing their best on the job.

Projects managers will also try to meet the esteem needs of their team members by acknowledging their contributions and celebrating successes. This can be an award formally presented at a celebration dinner, or a simple email expressing thanks. Anecdotally, it doesn't seem that the size or formality of the acknowledgement matters much, what is important is that it is given sincerely.

Understanding Team Development

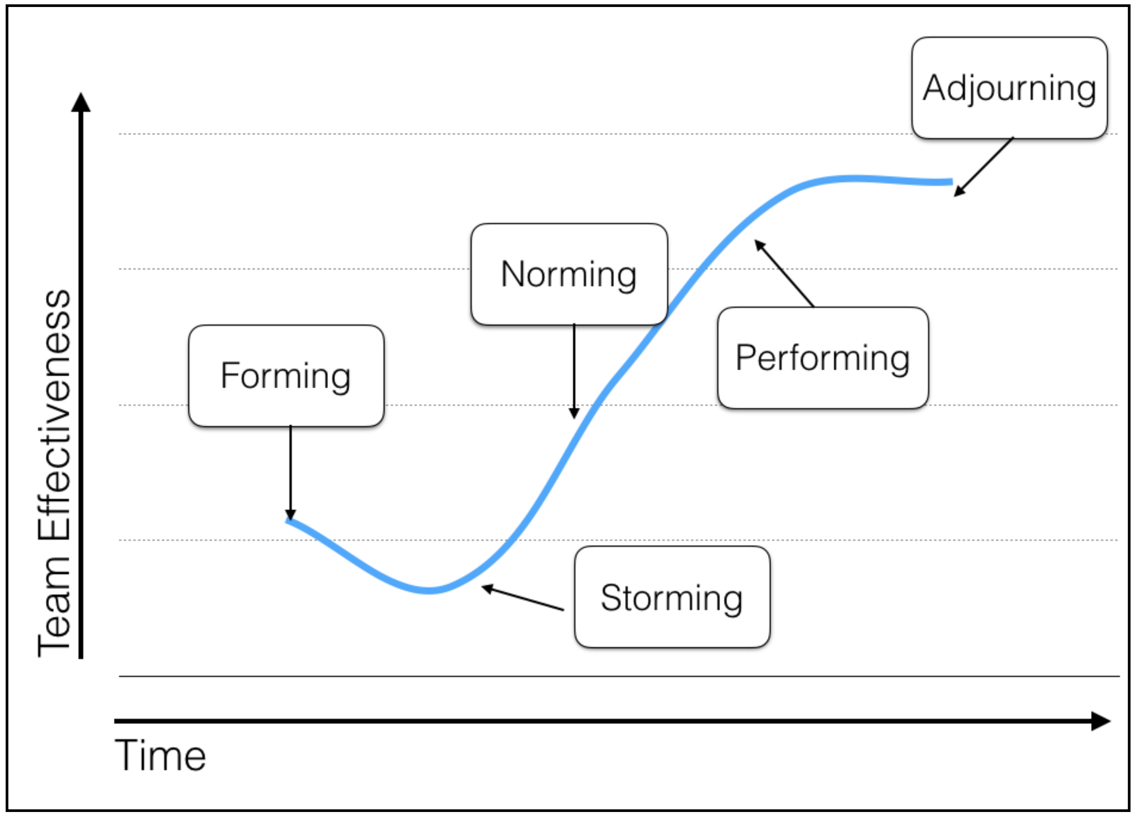
A number of management professionals and academics have studied project team development. Let's review the model that PMI considers the most valuable in understanding team development.

Tuckman's stages of Team Development

Dr. Bruce Tuckman observed that teams go through a series of developmental stages: Forming, Storming, Norming, Performing, and Adjourning. Each stage has predictable characteristics.

> **Forming:** The group is brought together for the first time. The team is orienting themselves to the task at hand. At this stage, there maybe little agreement on how to approach the project and team members may struggle with understanding the purpose of the project. The project manager needs to provide **guidance and direction** during this stage.
>
> **Storming:** Team members are trying to figure out their roles in the group. Conflict and power struggles are common, but so is a clearer vision for the group. During this time of inter-group conflict, the project manager needs to provide **support and coaching**.
>
> **Norming**: At this stage, the team will have developed a consensus regarding roles, processes and approach to the work ahead. The project manager should participate by working as a **facilitator** for the group.
>
> **Performing:** At this point the group has a clear vision and purpose and is focused on meeting performance goals, project milestones and other benchmarks. The project manager should be able to **delegate** more and more responsibility to the team, with less supervision.

Figure 2.2 Stages of Team Development



Team performance depends on the stage of development the team is in. Note that during the storming period, the effectiveness of the team may decrease substantially.

Adjourning: Once the project is completed, the team should collect lessons learned and transition to other projects or roles. The project manager should provide **recognition** of the work done by the team and help them transition to their next project (provide recommendations, etc.)

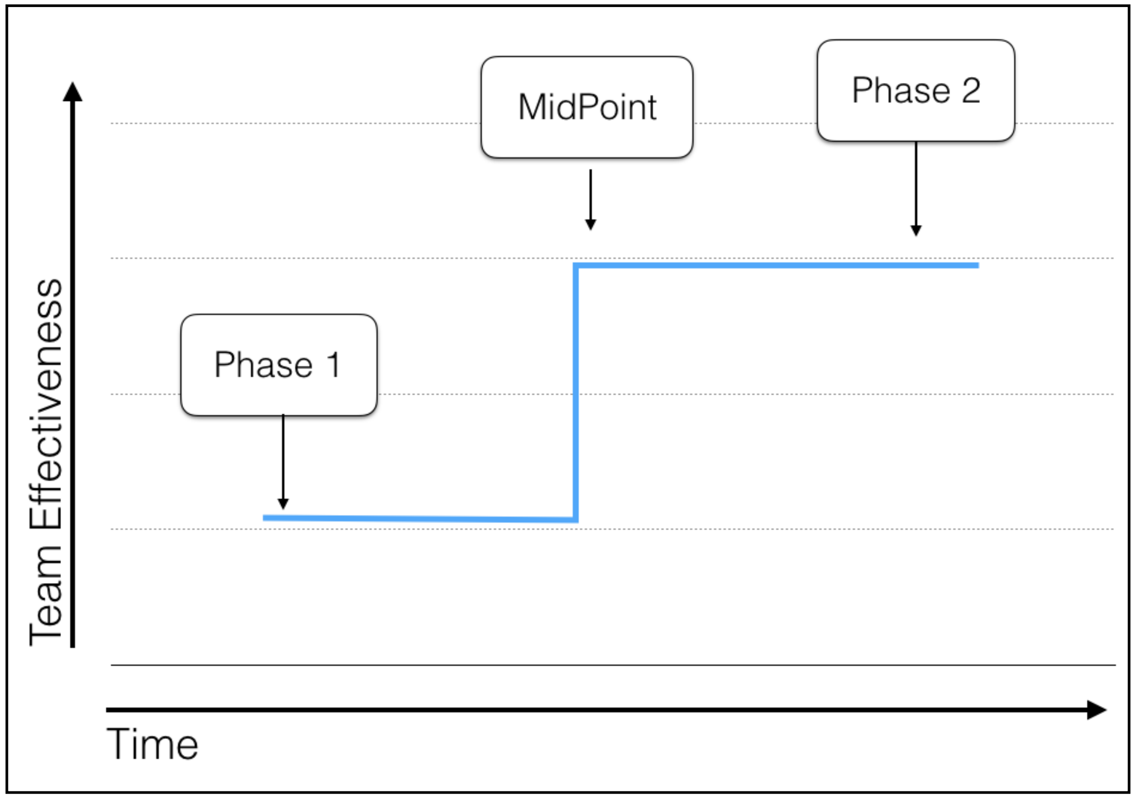
Fast-tracking Team Development.

Project managers who can quickly move the team from the Forming stage to the Performing stage will have huge advantages in terms of performance. To do this, project managers incorporate team building activities into the project.

Starting the project with some team building activities will let the team start to form, resolve interpersonal conflicts and develop norms of behavior in a low-risk environment. Unfortunately, some project managers perceive taking time for team building as a waste of time. However, time invested here pays off with a much more motivated and better performing team.

There are lots of opportunities to incorporate team building activities into the planning process. Perhaps the most important process a project manager can facilitate is helping team members learn to trust each other.

Sidebar 2.2 Gersick's Punctuated Equilibrium model



Under some circumstances teams will not follow Tuckman's stages of team development. Dr. Connie Gersick observed a second model in some situations in which, teams start with a low level of performance and then go through a period of process re-engineering and re-organization that allows them to have a breakthrough in performance levels. Gersick divides her model into Phase 1, a Midpoint, and then Phase 2. Often this re-organization is due to failure to meet deadlines or other reasons that require the team to take radical action. This type of team development is not generally embraced by project managers.

Section 3

Stakeholders

Stakeholders are not just those who are paying for, or will benefit from, our project. They include **anyone** who can have an influence on our project. Failure to consider the interests of stakeholders can lead to significant delays or even the failure of a project.

Stakeholders

A project stakeholder is anyone who can have an **interest** in or **influence** on our project. Project managers should consider all the possible stakeholders for a project, no matter how little interest or influence those stakeholders might posses. Failure to do so can lead to serious problems. Here is one simple example:

> A developer in Columbia, Missouri, started a project to build a new student housing complex in the campus/downtown area, an area considered by many local citizens to be historic. The developer decided that the only external project stakeholders were the Columbia City Council and the Planning and Zoning Commission, since those were the governmental bodies which gave formal approval for the project, issued building permits, etc. The developer quickly got a development agreement approved by both of these bodies and set off to start the project.
>
> The citizens of Columbia were startled to hear that a 400-bed apartment had been approved for construction in their treasured downtown. A large group of citizens did not like the proposed structure, and an even larger group disliked the hasty approval of the project. These citizens organized a successful petition drive to reverse the city Council's decision, and causing many delays and additional expenses for the developer and city. While the citizens of Columbia were not paying for the development, and did not have to approve of the development per se, they ultimately wielded a large amount of influence over the project.

A proper stakeholder analysis would have identified the city's citizens as an important stakeholder group; a group that should have been informed about plans for a new downtown apartment complex well before it was approved.

Stakeholder Influence and Interest

How we manage and interact with project stakeholders will depend on what level of **influence** (or power) they have over our project, and what **interest** they have in the project. These two aspects about a stakeholder are independent of each other:

- A powerful CEO might be able to swoop down and kill your project, or take away resources at any moment, but have very little interest in your project. In this case, the stakeholders power is high and the interest is low.
- Likewise, someone in another division might have a high level of interest in your project because of the impact it will have on them, but very little power to help or hurt your project.

Identifying Stakeholders

The first step in managing stakeholders is to identify the stakeholders for our project. There are several general categories of stakeholders that we can start with:

Internal Stakeholders

These are the people within our own organization. They can include:

- **Project champion or sponsor.** In some organizations, an upper-level executive will be charged with, or volunteer to be, project's champion or sponsor. This person acts as the liaison between the project team and upper management. They may provide the project manager with direction, information about how the project fits into the company's strategic goals, and assistance with getting the resources needed to complete the project. The best project sponsors are cheerleaders for the project, enthusiastically supporting the project and its team members.
- **Top management.** Other members of the top management maybe interested in a project for a number of reasons from strategic planning to resource allocation.
- **Functional managers.** Depending on the organizational structure of the company (see the section on Organizational Structures), the project may need talent resources from other departments, and it will be the functional managers who will be assigning personnel to the project. A good working relationship with the functional managers is vital to getting the resources that are needed for the project to succeed.
- **Project Team.** The project team is a very important stakeholder, with a great deal of influence. It seems obvious that the project team would want the project to succeed, but it is important to realize that the team might be composed of individuals with different and competing goals for what they want to see out of the project.
- **Shareholders and Owners.** Those who a vested financial interest in the future of the company will have a great interest in how resources are being used for a project and the goals of the project.

External Stakeholders

These are people or groups not directly employed or invested in our organization. External Stakeholders may include:

- **External customers**. If our project is being completed for the benefit of a paying customer, that customer will have a high level of interest and influence on the project.
- **Government.** A project may involve processes, work, materials, or other issues that may be subject to regulation or approval by a governmental organization. Certainly an organization must adhere to regulation regarding hiring, firing, health and safety of employees. Heavily regulation industries (financial, pharmaceutical, manufacturing, et.) will have their own set of special regulations and rules to follow.
- **Subcontractors and Suppliers.** If an organization doesn't have expertise or time requited to perform work on a project, subcontractors are often used. These subcontractors will have a high level of influence on the project (price and performance) and hopefully a high interest as well. Likewise, potential suppliers of raw materials and goods for a project will also interested and the quality of their work and materials will influence the project.

Stakeholder Identification & Analysis Tools.

Stakeholder analysis allows us to identify, classify, and develop a plan for managing project stakeholders. There are several tools we can use to help us in this process.

Stakeholder Register

A Stakeholder register is a tool that allows the project team to identify the stakeholders in a project and to attempt to rank their importance to the project. Table 2.3.1 presents a typical stakeholder register, that collects the following information:

- **Name.** The name of the stakeholder
- **Project Role.** The role the stakeholder has on the project. Examples include sponsor, customer, regulator, resource owner, etc
- **Major Concerns.** What are the major items of concern to the stakeholder?
- **Relationship Owner.** The member of the project team designated to manage the relationship with the stakeholder. For high priority stakeholder relationships this should be the project manager.
- **Importance.** How important is the stakeholder to the success of the project? Do they have the power to help or hurt the project?

- **Interest**. How interested is the stakeholder in the project? Do they have a strong interest in the outcome of the project ? Or are they just aware of the project and largely indifferent to its success or problems?
- **Score.** Score is calculated by multiplying the previous two fields together. Higher values identify stakeholders who will be high priorities for involvement in our project and with whom we must maintain communication.

Using a register can help your team track and analyze the stakeholders in your project. While identifying stakeholders is listed as an initiation process, realize that it is a process that may be initiated throughout the project life cycle. As new phases of the project begin we will re-evaluate our stakeholder register and update it.

Stakeholder Mapping

A stakeholder map places a stakeholder in a particular quadrant relative to the influence and interest of the stakeholder. Where the stakeholder lands in this map will determine how closely you manage and involve that stakeholder; see Table 2.3.2 for details.

Stakeholder Management

The process of identifying stakeholders may yield hundreds of stakeholders. Often individual stakeholders can be grouped together and a management strategy can be applied to that entire group of stakeholders. An important job of the project team and the project manager is to develop a strategy for managing relationships with stakeholders. It is important to take time to think through how to manage project stakeholders so that they become an asset to the project and not a problem. Here are some basic steps that can help you develop a plan for each stakeholder/stakeholder group:

1. **Think about what you need from each stakeholder**. What resources, advice or expertise can they provide? Will you need their approval to proceed at some point? Will they play a direct role in performing project work?
2. **Develop a message strategy for each stakeholder.** What information does this stakeholder need in order to help the project and make decisions? What performance metrics will they want to see and how should that be presented? How often should we communicate with this stakeholder and what is the mode of communications?
3. **Identify actions that you can take to involve each stakeholder in the project**. Should they be involved in the kick-off meeting and/or weekly project update meetings, invited to help with the risk identification process, or asked to help with the development of project plans?

Table 2.1 Stakeholder Register

Name	Project Role	Major Concerns	Relationship Owner	Influ. (1-5)	Interest (1-5)	Score

Table 2.2 Stakeholder Mapping

<table>
<tr><th colspan="2"></th><th colspan="6">Importance of Project to Stakeholder (interest)</th></tr>
<tr><th colspan="2"></th><th>None or Unknown</th><th>Little</th><th>Some</th><th>Moderate</th><th>Significant</th><th>High</th></tr>
<tr><th rowspan="6">Stakeholder Influence (Power)</th><th>High</th><td colspan="3" rowspan="3">C</td><td colspan="3" rowspan="3">A</td></tr>
<tr><th>Significant</th></tr>
<tr><th>Moderate</th></tr>
<tr><th>Some</th><td colspan="3" rowspan="3">D</td><td colspan="3" rowspan="3">B</td></tr>
<tr><th>Little</th></tr>
<tr><th>No or unknown</th></tr>
</table>

General Strategies for managing Stakeholders based on a Stakeholder Map.

Box A: Stakeholders who have a high degree of influence and interest on the project, The project team will need to work closely with these stakeholders and involve them in project planning.

Box B: These Stakeholders have a high degree of interest in the project, but less influence, or power, to affect the project. These stakeholders need to be keep informed of project progress.

Box C: Stakeholders with high influence but little interest. These stakeholders need to be kept satisfied and informed about the project so they are not surprised if there are changes, or delays. These stakeholders can be a source of risk to the project.

Box D: Stakeholders in this box, do not require much interaction from our project team. These stakeholders should be monitored in case their level of interest or influence changes, but are generally the lowest priority for our team.

Chapter 3

Project Management and the Organization

Chapter 3 Overview

An organization's structure, culture, and social norms have a huge influence on that organization's ability to successfully complete projects. In this chapter, we'll look at how organizational structure can impact the role of the project manager and project team members.

The first section will explain the ways that organizations can be structured and the relative advantages and disadvantages of those structures for the successful completion of projects. The following organizational types will be discussed.

1. Functional
2. Matrix
   - Weak Matrix
   - Balanced Matrix
   - Strong Matrix
3. Projectized
4. Dedicated Project Team

Learning Objectives:

- Understand the different types of organizational structures.
- Explain the relative advantages and disadvantages of each structure as it relates to project management.

Section 1

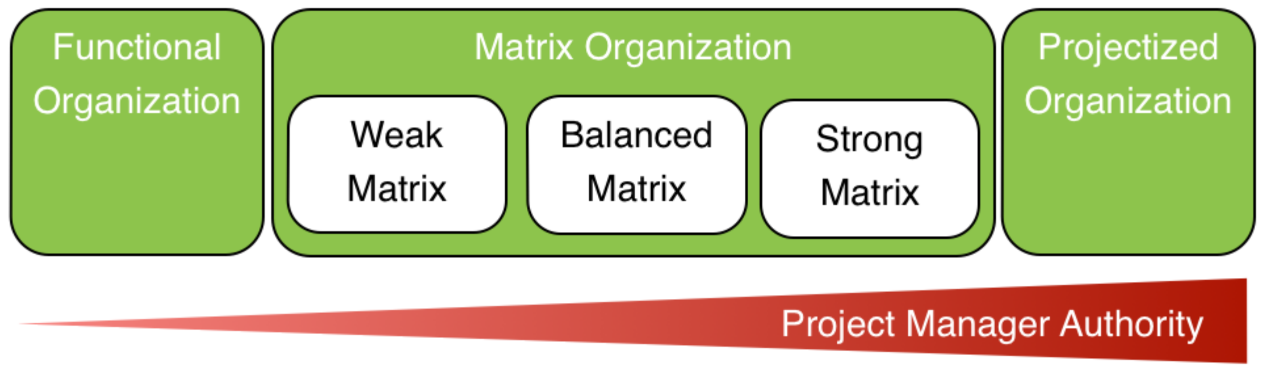
Organizational Structures

There are three three broad structures by which an organization can be organized.: functional, matrix, and projectized. These structures represent a continuum, from structures where the project manager has very little authority (functional) to those where project managers have very broad power (projectized) (See Figure 3.1).

There have been many studies about the impact that organizational structure has on project success, and it is not uncommon for corporations to change their organizational structure in order to increase their relative success in executing projects on time and within budget. This type of change takes great effort and may take a long period of time to fully implement.

Instead of changing their entire structure, an organization may elect to create a dedicated project team in order to carry out a critical project without reorganizing the entire enterprise. This way, they can get many of the same benefits of the

Figure 3.1 Project Manager Authority and Organization Type



projectized organization without reorganizing the enterprise. This approach is not without risk, as we'll explore in the section on dedicated project teams.

Functional Organizations

Large organizations are traditionally organized by function into various departments, with staff in each department reporting to a departmental manager or head of department. This allows for groupings of specialists within the organization where they can work together, share knowledge and prioritize their work.

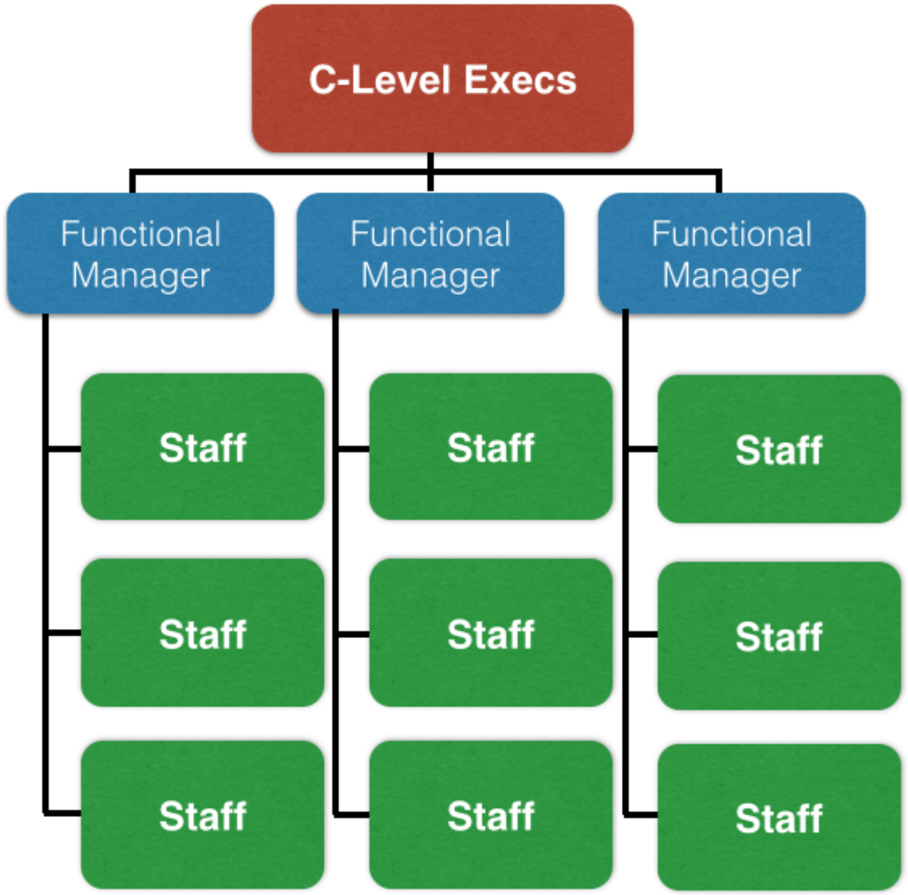
Traditional functional departments might include:

- Human resources
- Accounting
- Procurement
- Marketing
- Sales
- Shipping

These functional units work independently of each other, and the functional managers serve as conduits for communications and collaboration (See Figure 3.2). This type of structure is very efficient for operations management where continuous process improvement can be conducted on all regular departmental operations. However, it is not optimal for the completion of projects.

Projects often require work across disciplines. In the functional organization, with staff isolated inside their departmental "silos," communication is directed through the functional managers. These managers often have differing priorities, which can make communications slow and error-prone in an functional organization.

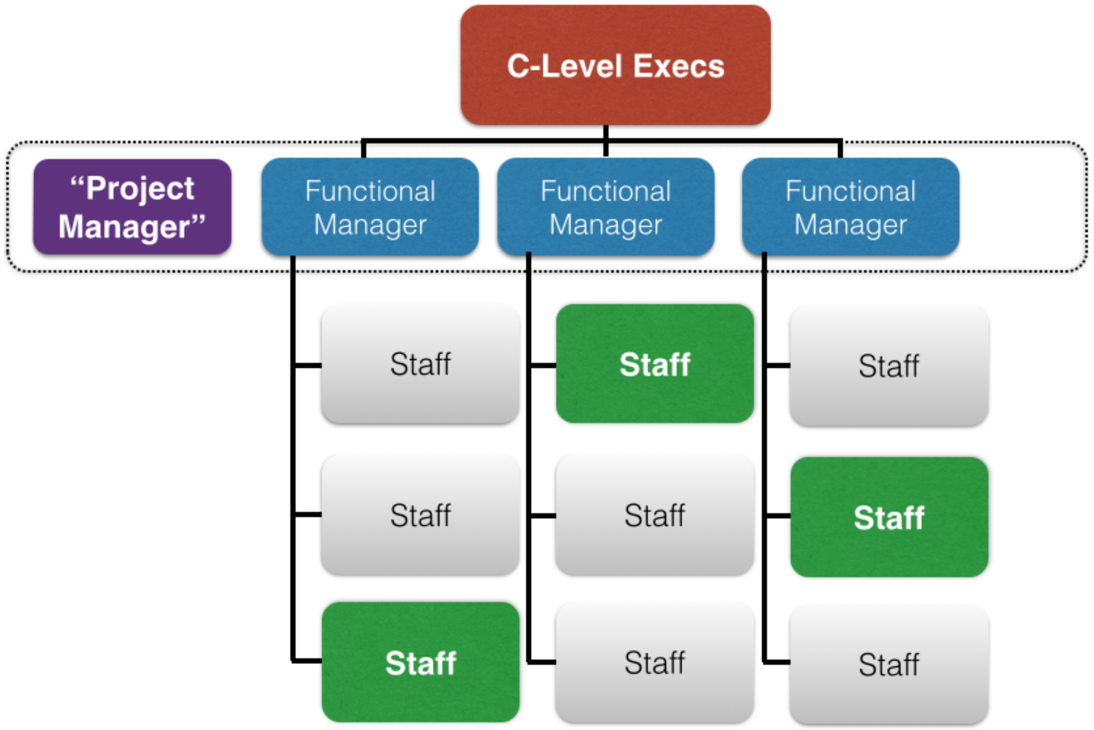
Figure 3.2 Functional Organization Structure



Functional Managers have control of project resources in a functional organization. Coordination of a project is done between Functional Managers.

The success of projects within a functional organization depends on functional managers working together and cooperating. While someone maybe designated as the project manager for a particular project, that person may not have much authority (See Figure 3.3). Often titles such as Project Coordinator, Project Scheduler, or Project Expediter will be used instead. Regardless of title, those in charge of projects are often put in the role of simply trying to maintain a schedule of what is happening.

Figure 3.3 A “Project Manager” in a functional organization.



The project manager has to work through the functional managers to get staff assigned to complete tasks.

PMI identifies the following project characteristics for projects conducted in functional organizations:

- Project Manager’s Authority: Little or None
- Resource Availability: Little or None
- Who Manages the Project Budget: Functional Manager
- Project Manager’s Role: Part-time
- Project Management Administrative Staff: Part-time

Projectized Organizations

Projectized organizations are at the opposite end of the organizational spectrum from functional organizations. Organizational energy and resources are focused on completing projects rather than ongoing operations. In a projectized organization, operations are minimal and the project manager has great authority over resources and personnel decisions.

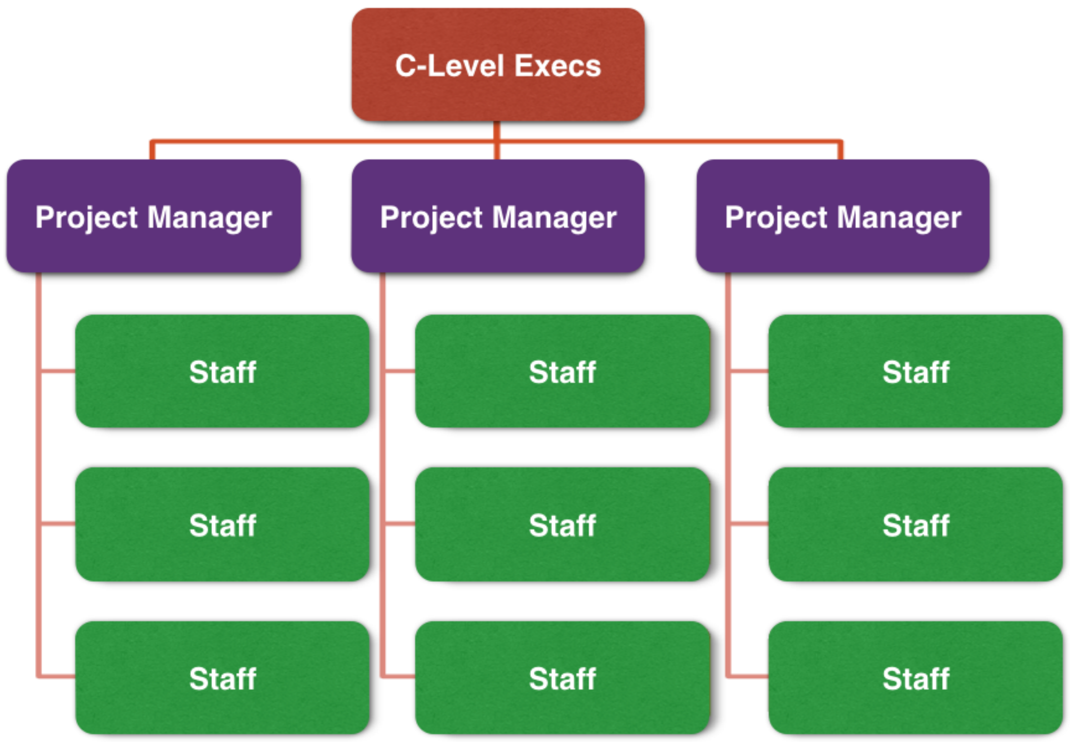
Projectized organizations may have organizational units called departments and these groups either report directly to the project manager or provide support services to projects.

In the project-based structure, personnel are specifically assigned to the project and report directly to the project manager (See Figure 3.4). The project manager is responsible for the performance appraisal and career progression of all project team members while on the project.

As you can imagine, employees in this type of environment are able to focus their loyalty to a project rather than their particular discipline. Not all people can succeed in such an organization, as they must adapt to the leadership styles and organizational skills of different project managers.

This is the most efficient organizational type for conducting projects, and it is used in those types of organizations that bid on and undertake large projects—military, industrial, scientific, etc.—that may last several years.

Figure 3.4 Projectized Organizations



The project manager has a large degree of control over staffing and resource allocations in a Projectized Organization.

Examples of project-based organizations include construction companies, aeronautical manufacturers such as Lockheed Martin, and many software development companies.

This type of organizational structure can put additional stress on employees as they have no home to return to once their project is over, if they are not selected for a subsequent project. But it is generally considered ideal for project management since there is a significant reduction in the layers of bureaucracy that a project manager must navigate.

PMI identifies the following project characteristics for projects conducted in projectized organizations:

- Project Manager’s Authority: High or Absolute
- Resource Availability: High or Absolute
- Who Manages the Project Budget: Project Manager
- Project Manager’s Role: Full-time
- Project Management Administrative Staff: Full-time

Matrix Organizations

While the functional structure may work well in times of little change, it has some serious limitations when the success of a company depends on being adaptable. A matrix structure tries to combine the strengths a functional organization provides for operations management with the strengths a projectized organization provides for project management.

In a matrix organization, the functional and project manager share authority and responsibility. This can lead to several negatives:

- Employees can have two supervisors to which they have to report, breaking the rule of a solitary chain of command.
- Employees have to balance their work between the needs of the projects they are working on, and their functional unit.
- Supervisors may find that it is more difficult to achieve a consistent rate of progress since employees are often pulled in different directions.
- Costs and communication channels can increase.

However, there are several advantages to a matrix structure in terms of projects:

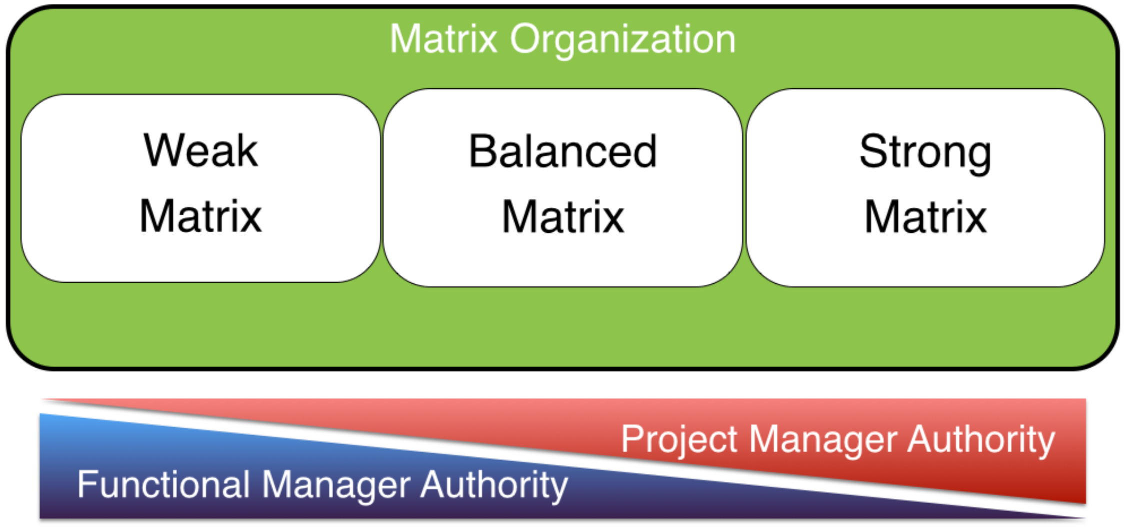
- It significantly disrupts the communication "silos" of a functional organization, creating a more horizontal structure for teams and increasing the flow of information.
- Allows people to concentrate of their areas of speciality, and bring that strength to current projects.

PMI recognizes three types of matrix structures, as described below (See also Figure 3.5).

- **Weak Matrix:** The project manager has less over resources and people than the functional managers. Project managers in a weak matrix may go by other titles such as a project coordinator or project scheduler.
- **Balanced Matrix:** In a balanced matrix, the project manager and functional managers equally share authority over resources and staff. This allows the organization to experience the "best of both worlds" by receiving the benefits of a projectized organization and functional organization at the same time. However, this system presents many challenges:
  - Functional managers and project managers have to work well together and maintain regular communications.

    - Staff will have two managers to which they have to report, breaking the concept of the chain of command and organization.
    - If functional and project managers have conflicting priorities, subordinates may be unable to meet expectations.
- **Strong Matrix:** In a strong matrix, the project manager has more direct control over resources and staffing, while the functional manager will provide support to the project staff in terms of hiring, technical expertise, and professional development. Of all the matrix structures, this is the one in which the project manager has the most authority, and the functional manager has the least

Figure 3.5 Matrix Organization



Matrix organizations are a mix of the good (and bad) aspects of the functional and projectized organizations.

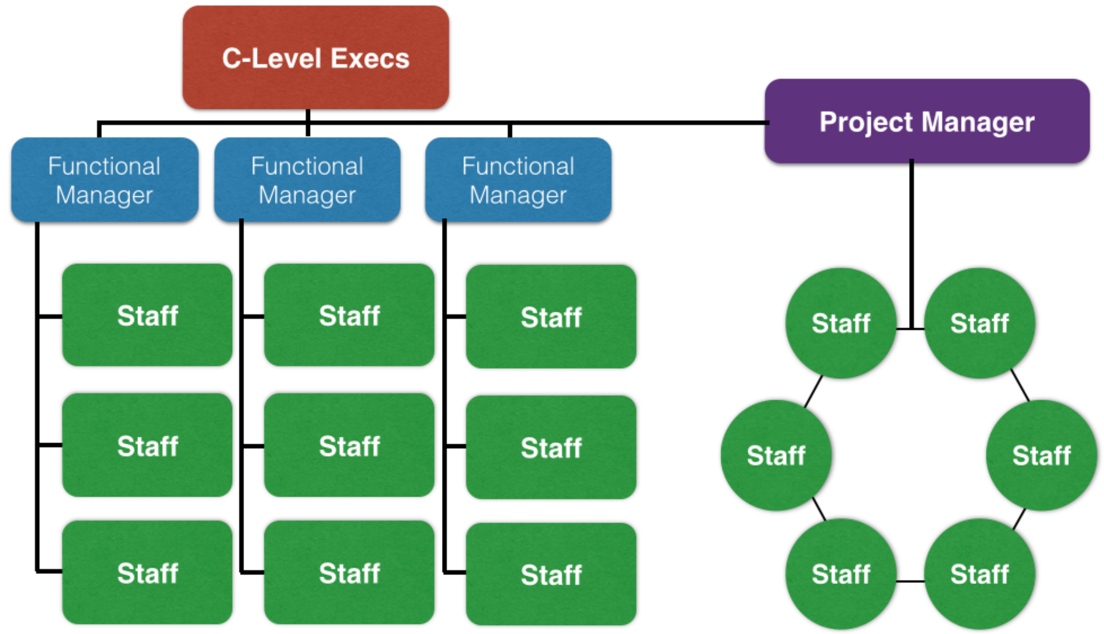
Dedicated Project Team

Many functional organizations find that they often need to carry out important projects but do not want to change their entire organizational structure. Recognizing the advantages that are achieved by giving authority to a project manager, functional organizations often organize dedicated project teams where a project manager can have authority over the staff assigned to that particular project. The project manager and project team members are sometimes located in a special office, away from the desks and duties that they normally have within the functional organization (See Figure 3.6). This can be a very effective way to complete projects. However, some difficulties can arise:

- Temporary loss of staff from the functional groups.
- Integration of project team members back into the functional organization after the project is completed can be difficult.
- An "us versus them" mentality, where the people on the project team are deemed to be more special than those working in the functional departments. There have been numerous case studies of conflict arising from dedicated project teams.

A classic case of the use of a dedicated project team—and the problems it can cause to the functional organization—was when Steve Jobs picked the best and brightest engineers from Apple to work on the development of the macintosh computer. The project was very successful, but there was a lot of tension between the project team and the functional organization.

Figure 3.6 Dedicated Project Team

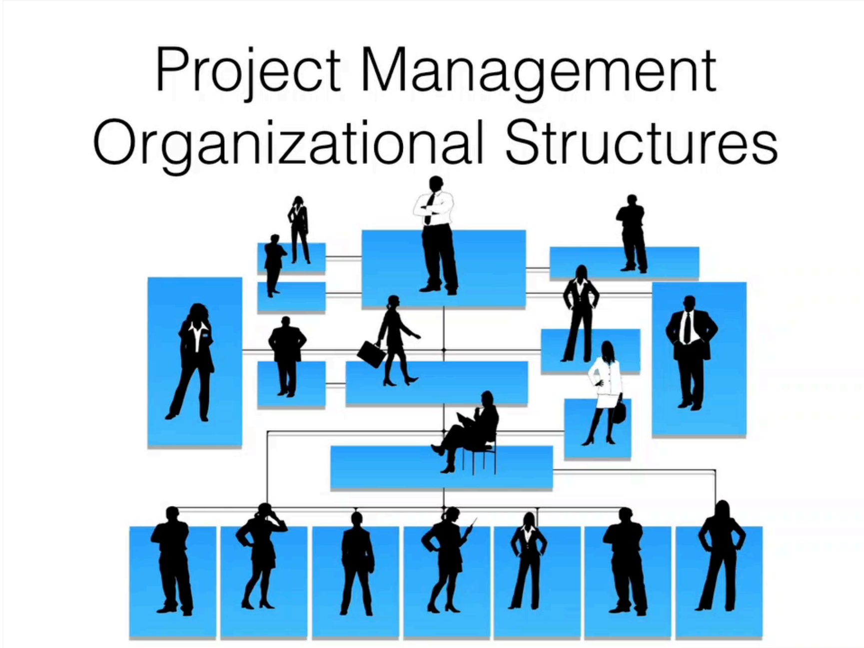


By leaving the functional organization in place and breaking off a team of staff that directly report to a project manager, functional organizations can gain significant efficiencies in conducting projects.

Summary

How effective our organization is in conducting projects on-time, within scope and on-budget will be influenced by the type of structure in which we operate. Watch the Review of the PM Organizational Structures (Video 3.1) for a summary of what you have learned and a look at some of the data on project effectiveness. Table 3.1 below summarized PMI's evaluation of project characteristics across various organizational structures.

Video 3.1 Review of the PM Organizational Structures.



You can also view this video at: http://pmf.video/video4

Table 3.1 PMI's evaluations of the project characteristics in various organizational structures.

	Organizational Structure				
	Functional	Matrix			Projectized
		Weak Matrix	Balances Matrix	Strong Matrix	
Authority of Project Manager	Minor or None	Low	Low to Moderate	Moderate to High	High or Absolute
Project Manager's Role	Part-Time	Part-Time	Full-Time	Full-Time	Full-Time
Budget Control	Functional Manager	Functional Manager	Shared between Functional & Project Manager	Project Manager	Project Manager
Resources for Projects	Little or None	Low	Low to Moderate	Moderate to High	High or Absolute

Chapter 4

Project Charter

Chapter 4 Overview

This chapter explores the main guiding document for any major project: the project charter. The project charter lays out what the project is about and what will be needed to complete the project.

The one and only section in this chapter explores the project charter, which:

1. Provides the project manager with the “mandate” for the project.
2. Provides information on the constraints, business case, stakeholders and assumptions for the project.
3. Is used to develop other planing documents (i.e, serves as an input for other planning processes/documents).

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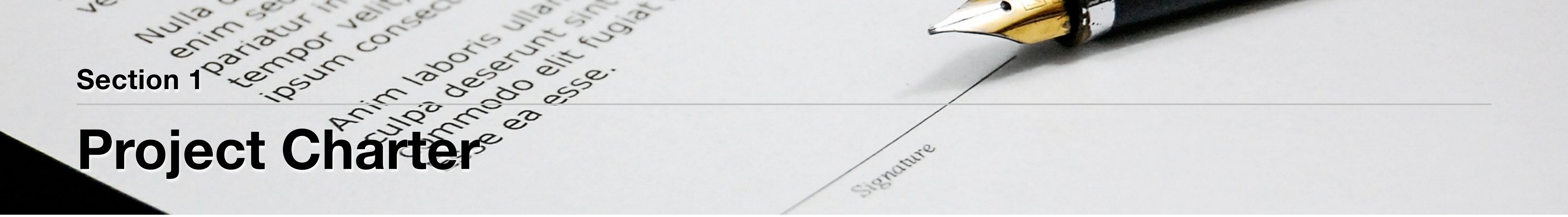
Learning Objectives:

- Understand the major portions of a project charter and the information provided in each.
- Understand the value of a project charter to project success.



Section 1

Project Charter

Developing the project charter is an initiating process designed to produce a document that outlines a project’s framework and major goals, provides initial identification of project stakeholders and risks, and authorizes the project manager to move forward with the project. Developing the project charter produces a clear mandate for a successful project.

The Project Charter

The project charter provides essential information about a project and is used to gain authorization to start the project. The charter document can be just a couple pages in length or can be 50-100 pages. Ideally it will be short (less than 5 pages) and written in clear and concise language so that anyone who reads it will have a clear understanding of the project, regardless of their technical background. Most project charters include a place at the end of the document for approval sign off by the project sponsors or customers (i.e. those people that are paying for the project).

The project charter is used by the project manager during the planning process. The project charter informs the project manager about what skills will be required on the project team, as well as the general scope of work for the project.

Some organizations forgo creation of a project charter, viewing it as a document that merely takes time to create and contains information that "everyone already knows." This can be a big mistake. The charter can be referenced by the project manager and stakeholders if some of the goals of the project are not met or they are asked to do something outside the scope of the project. A well drafted project charter can prevent political interference in achieving the goals of the project and reduce scope creep.

The charter is developed by the key stakeholders to outline their common vision for the project (sometimes with the help of a project manager or PMO). Creating the charter provides an opportunity to check stakeholder assumptions regarding the purpose of the project. Any differences in understanding about the goals of project can then be resolved as quickly as possible.

What Should be in a Charter?

There are many templates available for project charters and these vary greatly in the content and level of detail. (The PMI affiliated web site ProjectManagement.com offers a number of project charter templates at http://pmf.video/link2.) At a minimum, good project charters will contain the following sections.

Background

The background should provide a broad overview of the project and answer the following questions:

- What is the purpose of the project?
- Where did the project originate? Have we conducted similar projects in the past?
- Who is the project manager and what level of authority does the project manager have?

Business Case

The Business Case describes why this project was selected over others and answers the following questions:

- Why was this project selected to move forward (project justification)? What selection criteria where used? (Project selection techniques are covered in a later chapter.)
- What problems is this project solving or what opportunities is it creating? What are the high-level requirements?

Goals

Listing the goals for the project ensures that the stakeholders will not be disappointed when the project is completed. This section should answer the following questions:

- What are the broad goals of this project?
- How will we know if the project is a success (what are our metrics for success)?
- Are there industry standards that we are trying to meet or benchmarks for performance that we want this project to attain?

Key stakeholders

This section describe the key stakeholders and their interest in the project. This doesn't have to be an exhaustive list of stakeholders, but should contain a list of people that are interested in the project, as well as people who will pay for, or benefit from, the project.

Major milestones

This section provides a summary of the major milestones for the project. A listing of any hard deadlines for the project should be included. Milestones can relate to project work (when are major deliverables expected to be complete?) as well as invoicing and payment deadlines.

Project budget

The project budget section should provide a summary of the budget for the project and information about how it was determined. It answers the following questions:

- What is the initial budget for this project?
- How was that budget developed?
- Are the numbers used for budgeting rough estimates based on top-down estimation techniques, such as analogous or parametric estimating, or are they hard constraints?
- What contingency funds have been allocated?

Constraints

This section will list any constraints on our project or the final product. For example, if we are creating a website, does it need to be viewable on mobile devices as well as PCs? Are there regulatory constraints that our product must meet if it is to be successfully marketed in certain countries (for example, not using lead solder). Are there other limitations that we need to consider in terms of our scope of work?

Assumptions

What assumptions are we making about this project or the environment in which we are operating? If we're using a lot of copper for wiring or other uses in our project, are we assuming that the price of copper will remain stable over the lifetime of the project? Are we assuming that we will be paid on time, and that are key programmers or engineers will not retire or find other positions? This will help the project manager mitigate risks later in the planning process.

Risks

This section will list the risks that can currently be identified. This list will be expanded when a formal risk management plan is developed, but, for now, what do the stakeholders who are creating the project charter believe are the major risks involved in this type of project? The list of assumptions will help inform this list of risks.

Project authorization

This part of the project charter will provide a place for the project sponsors in the company or organization to sign off. By signing the document the sponsors are giving the project manager authorization to proceed with developing the planning documents and to get the project started. Obviously the project manager will be communicating regularly with those who are authorizing the project.

Figure 4.1 A short and well written project charter will ensure that everyone has the same vision for the project.

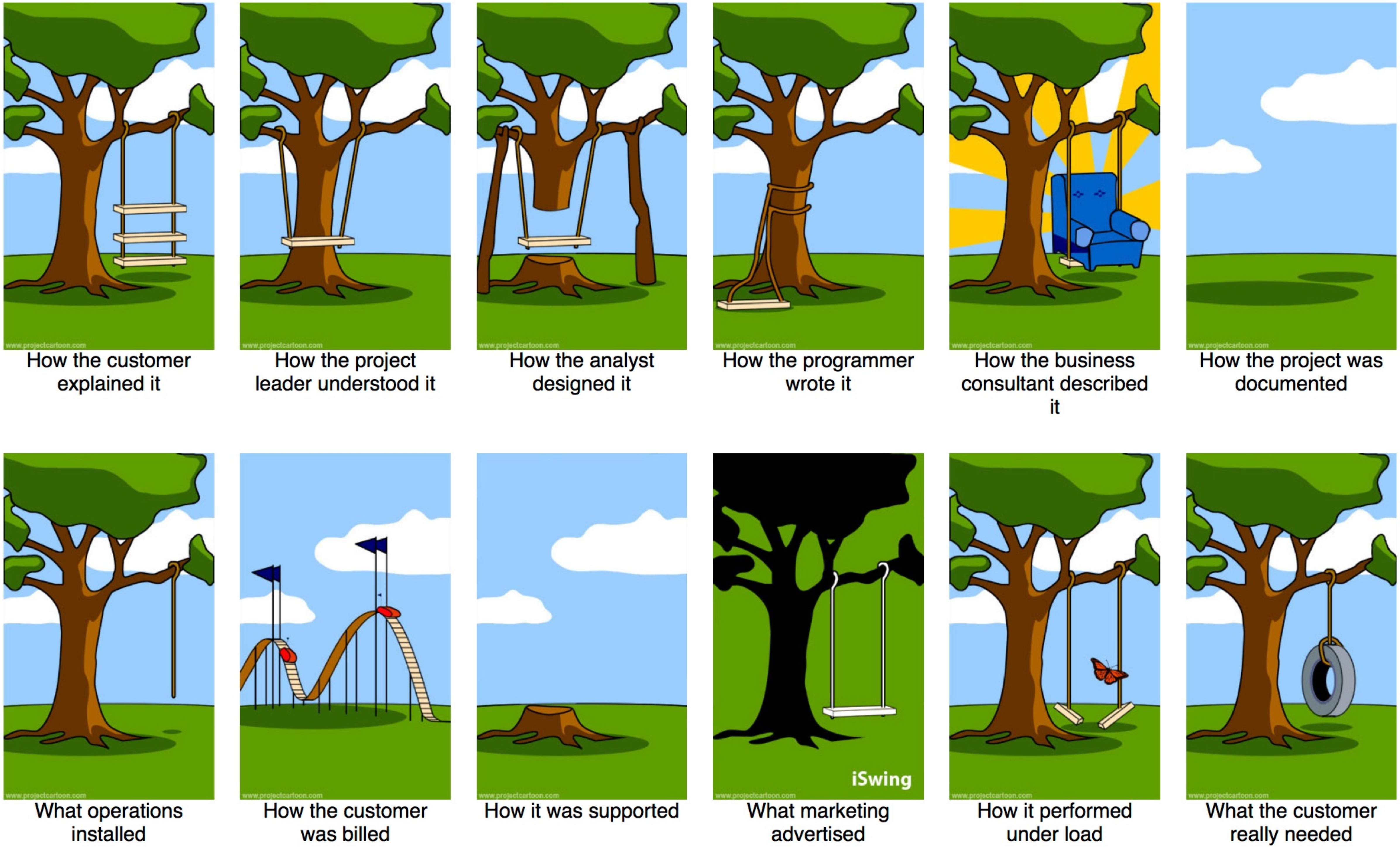
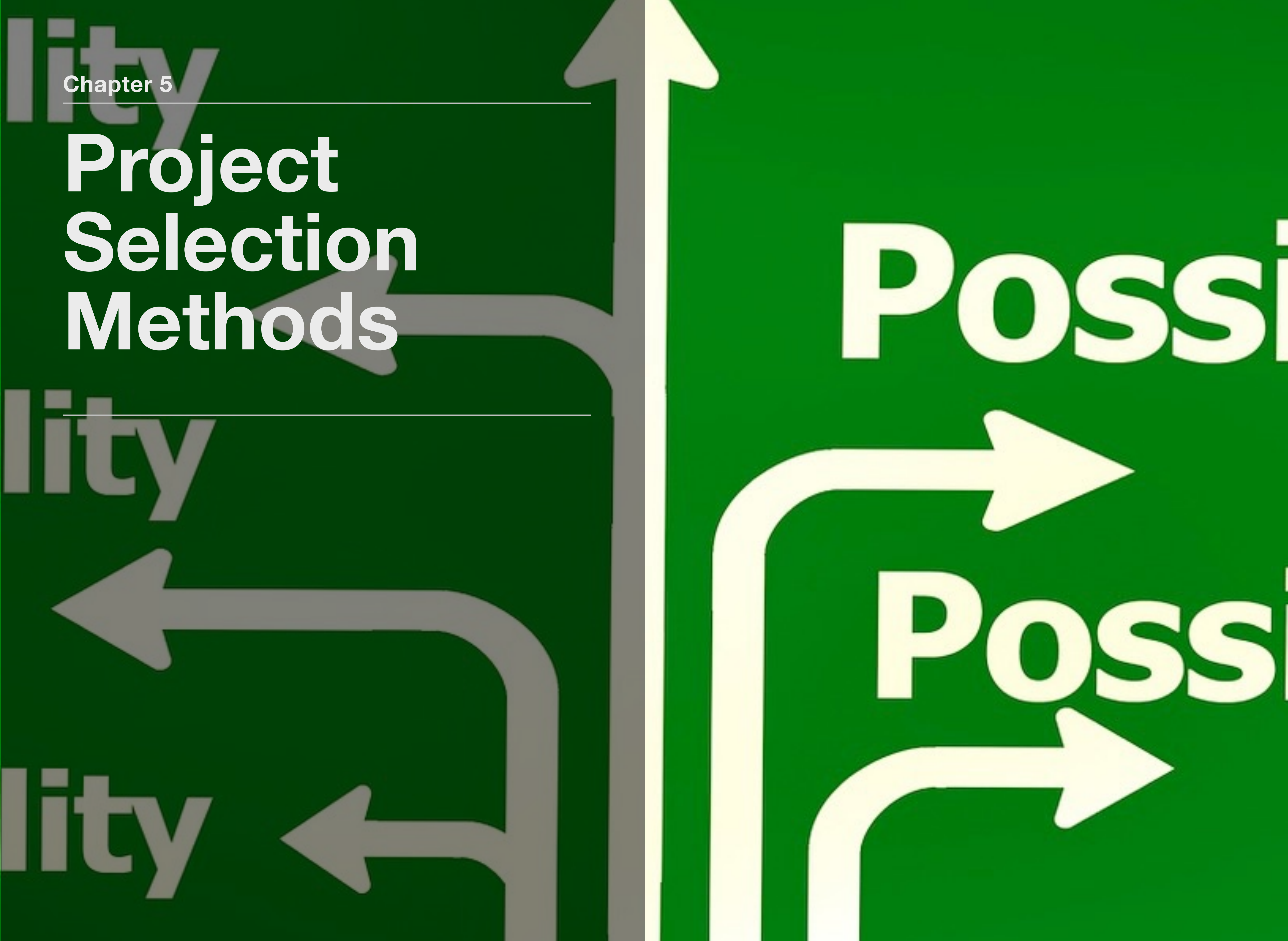


Image from http://www.projectcartoon.com/, shared via creative commons by attribute.

Chapter 5

Project Selection Methods



Chapter 5 Overview

The problem facing most businesses and organizations is not what projects are possible to do, but which projects should be undertaken given current resource and time limitations. An organization may be considering projects to implement internally or projects for external customers.

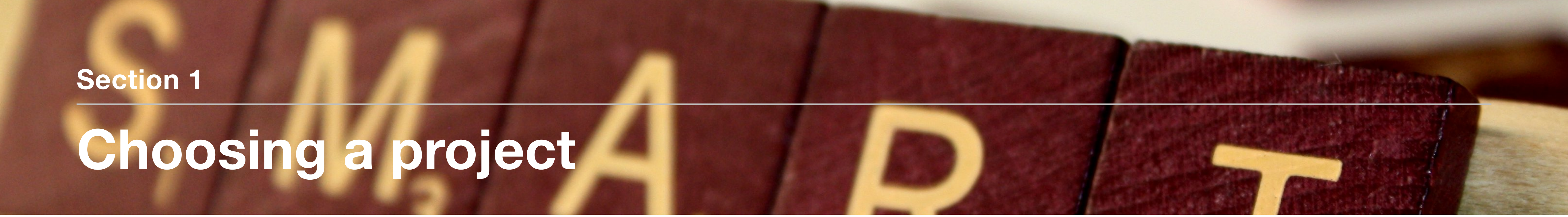
This chapter reviews the various types of project selection methods, from Murder Boards to calculating Net Present Value. It also describes the costs that project managers need to understand (opportunity costs, sunk costs, and ongoing maintenance costs) as well as other factors that can affect why a project might be selected.

The first section in this chapter, “Choosing A Project,” reviews classifications of projects and the basic criteria that are used for project selection.

The two remaining sections review methods for comparing and selecting projects from among many choices. The section on Qualitative Scoring Methods discusses two methods that can be used to solicit input from stakeholders and experts about the potential of various projects. The section on Economic Scoring Methods presents several common quantitative measures for assessing a project’s potential performance.

Learning Objectives:

- Explain the three broad categories of projects.
- Understand SMART criteria for developing and defining projects.
- Explain the types of costs that need to be considered (Project, Opportunity, Sunk Costs, and Total Cost of Ownership).
- Understand how to use a simple checklist and a weighted scoring model.
- Know the relative advantages and disadvantages of various scoring models.
- Be able to calculate Payback, Net Present Value, Internal Rate of Return and Benefit-Cost Ratio.
- Understand how to interpret the values when given the results of a Payback, Net Present Value, Internal Rate of Return or Benefit-Cost Ratio analysis.



Section 1

Choosing a project

Companies and organizations must employ some method to choose the projects that are most likely to move the organization forward toward meeting its strategic goals. There are many methods for making decisions about which projects to undertake; some are simple and others are very complex. The method(s) that are chosen should reflect the priorities and values of the organization.

Keep in mind that project selection methods, however sophisticated, are only partial representations of the reality they are meant to reflect.

Project Types

There are three broad categories of projects to consider: Strategic Projects, Operational Projects, and Compliance Projects (Figure 5.1).

- **Strategic Projects** involve creating something new and innovative. A new product, a new service, a new retail location, a new branch or division, or even a new factory might be a strategic project, because it will allow an organization to gain strategic advantage over its competitors.
- **Operational Projects** improve current operations. These projects may not produce radical improvements but they will reduce costs, get work done more efficiently, or produce a higher quality product.
- **Compliance Projects** must be done in order to comply with an industry or governmental regulation or standard. Often there is no choice about whether to implement a project to meet a regulation, but there may be several project options to consider, any of which would result in meeting compliance requirements.

Figure 5.1 Three broad categories of projects.

SMART Criteria for Projects

In the early 1980s, George T. Doran introduced the SMART set of criteria for projects, goals and objectives. SMART is an acronym for **S**pecific, **M**easurable, **A**ssignable, **R**ealistic, and **T**ime-Related.   The smart criteria have been applied in many different areas of management, including project management. Let's take a look at each of Doran's criteria as they apply to project management.

Specific – A project needs to be specific about what it will accomplish. Unlike many organizational goals, the goal of a project should not be vague or nebulous. An organization may want to "make Columbia, Missouri a great place to live," but its projects need to focus on a specific goal; for example, to build a downtown farmers market. A project that is specific is one that can be clearly communicated to all team members and stakeholders.

A specific project goal will answer the five 'W' questions:

1. **W**hat do we want to accomplish?
2. **W**hy are we undertaking this project?
3. **W**ho is involved or will be affected by the project?
4. **W**here will this project be conducted?
5. **W**hich constraints (scope, time, money, risk, etc.) have been placed on our project?

Measurable – How will project progress and success be measured? What will be the measurable difference once our project is completed successfully? These measures should be quantifiable.

Assignable – Who will do the work? Can people be identified who have the expertise in the organization to complete this work? Or can the expertise be hired from outside of the organization?

Realistic – Is it realistic that the organization can achieve this project, given its talents and resources? This is a very important consideration for businesses of all sizes. Yes, it would be great to produce a new driverless car, but is that realistic given the resources that the organization has available?

Time-related – when will the project be completed and how long will it take?

These criteria can be very useful when defining a project. If the description for a project does not meet all these criteria, then it is time to go back to the drawing board and make sure that what is being described is really a project, rather than a program or strategic goal.

Costs

When evaluating potential projects, there are several types of costs that we must keep in mind: Project Costs, Opportunity Costs, Sunk Costs and Total Cost of Ownership.

Project Costs

Project Costs are those costs directly associated with the project, including:

1. Direct costs, such as materials, labor, and equipment.
2. Indirect costs, such as insurance and project manager labor.
3. Contingency funds and budgetary reserves.

These costs add up to the total estimated cost of our project. Details regarding how to calculate these costs are covered in later chapters.

Opportunity Costs

Whenever a project is selected to move forward, there are others that are rejected and will never be completed. We will never be able to reap the rewards of the projects we don't complete. The cost of NOT doing a project is considered the Opportunity Cost.

Here is an example to illustrate the concept of Opportunity Cost. Dave decided spend four years of his life at a university to get a college education. His education costs $12,000 per year, but he will be able to make $45,000 per year after he graduates. His other option was to go directly into the workforce and start out earning $20,000 per year. The income that he gives up by not going directly into the workforce is the Opportunity Cost of his decision. Eventually the investment in his education will pay off with a high salary over the long term.

In this example, one should also consider the Opportunity Cost of NOT going to college (the opportunity to make $25,000 more per year after four years of college). Table 5.1 on the next page shows the calculation of these opportunity costs. Five years after graduation, the individual with the college degree has a clear financial benefit from the experience despite losing four years of potential income.

Table 5.1 Opportunity Cost of a College Education.

Year	DIRECT TO WORKFORCE			FOUR YEAR COLLEGE DEGREE			
	Opportunity Cost of Not Having a Degree	Income	Return on Investment (ROI)	Opportunity Cost of Not Working	Cost of College	Income	ROI
1	$0	$20,000	$20,000	-$20,000	-$12,000	$0	**-$32,000**
2	$0	$20,000	$40,000	-$20,000	-$12,000	$0	**-$64,000**
3	$0	$20,000	$60,000	-$20,000	-$12,000	$0	**-$96,000**
4	$0	$20,000	$80,000	-$20,000	-$12,000	$0	**-$128,000**
5	-$25,000	$20,000	$75,000	NA	NA	$45,000	**-$83,000**
6	-$25,000	$20,000	$70,000	NA	NA	$45,000	**-$38,000**
7	-$25,000	$20,000	$65,000	NA	NA	$45,000	**$7,000**
8	-$25,000	$20,000	$60,000	NA	NA	$45,000	$52,000
9	-$25,000	$20,000	**$55,000**	NA	NA	$45,000	**$97,000**
10	-$25,000	$20,000	$50,000	NA	NA	$45,000	$142,000
11	-$25,000	$20,000	$45,000	NA	NA	$45,000	$187,000
12	-$25,000	$20,000	$40,000	NA	NA	$45,000	$232,000
13	-$25,000	$20,000	$35,000	NA	NA	$45,000	$277,000
14	-$25,000	$20,000	$30,000	NA	NA	$45,000	$322,000

The green highlight indicates the point at which it becomes more profitable to attend college.

Sunk Costs

Sunk Costs are those costs that have been put into a project and can't be recovered. In project management, a Sunk Cost is the money which we have already put into a project or idea. Sunk Costs should never be considered when making a decision, only future costs.

For example, ABC Corporation has spent twenty thousand dollars on developing an new iPhone app. Unfortunately, several similar apps have been released since the project began. As a result the potential profits of the app have been severely diminished. It will take another thirty thousand to complete the app. Some people on such a project will argue that since twenty thousand has already been spent, the project should be completed. However, ABC corporation can not recover the original twenty thousand dollars and investing another thirty thousand might just be "throwing good money after bad."

Sunk Costs are especially important to consider because of the fact that people don't make decisions just based on data, but also on emotions. Project Managers want their projects to move forward and are generally optimistic about the future. As a result, their judgement can be clouded by what they want to happen. It may be difficult for them to step back and realize that a project should be cancelled, rather than investing more time and money in a project that will not be useful or profitable.

However, with a project that produces a physical product or deliverable, such as a building, not all costs are sunk forever. When a building has outlived the useful life for which it was designed, it can still have some value as an asset.

For example, ABC Corp decides to build a new factory for 5 million dollars and calculates that the factory will have a useful life of 30 years before it needs to be upgraded or replaced. ABC Corporation will calculate the costs of building, financing, and operating the factory over 30 years, along with the revenue from the products produced by the factory, and then decide if it is a worthwhile project to pursue. Then, at the end of 30 years, the factory will still have some value. For example, the factory can be resold to another business or it can be torn down and the metal can be sold for scrap. This value is called **salvage value** and will be calculated into the financial calculations for a project.

Total Cost of Ownership (TCO).

When our project involves the creation of a physical product, we need to consider the cost of operating or maintaining that product after the project is complete. For example, consider the construction of a new school with 20 classrooms. Each classroom will have a digital projector for use by the teacher. If the project team just evaluates the projectors based on their initial cost and accepts the lowest bid that meets the technical specs, then over time the school may suffer higher costs for operating and maintaining the projectors. The total of the initial cost of the projectors (or any item) and the cost to operate (e.g., electricity costs) and maintain (e.g., cost to replace the bulbs) the projectors is called **Total Cost of Ownership, or TCO.**

Table 5.2 shows a sample comparison of the TCO of various projectors. Note that the more expensive projector will cost the school ~$7,700 dollars **less** in the long run.

Table 5.2 TCO for Projector Purchase.

	Projector A	Projector B	Projector C
Cost of Projector	$1,500.00	$2,500.00	$3,500.00
Cost of Bulb	$450.00	$350.00	$500.00
Bulb Life in Hours	3,000	5,000	9,500
Number of Bulbs required for 100,000 hours of use	33	20	11
Cost of bulbs over 200,000 hours	$15,000	$7,000	$5,263.16
TCO (Projector + Bulbs)	$16,500	$9,500	$8,763.16

Other Reasons for Project Selection

Before exploring the methods that are used for project selection, it is worth mentioning that sometimes projects are selected as a result of political or emotional considerations rather than purely objective comparison.

For example, a high-level executive may have an idea for a project, and the power to make sure it moves forward, regardless of the soundness of the project or its imagined benefits. These projects are referred to as “sacred cows,” because the project is being completed to meet the wishes of an executive or leader within the organization and can’t be killed off. This is simply a reality that many project managers face in their daily work. However, when you are taking a PMI exam, remember that PMI assumes that organizations will always follow a proper and rational approach to project management selection, and that politics will not intrude into the decision making process.

Project Selection Methods

Projects are selected by comparing the costs and benefits of potential projects. Some of the selection methods are more subjective than others, but all try to use a standard set of criteria to determine which project is the best for an organization to pursue. Methods can include:

- **Murder Boards.** A group of experts (internal and external) attempt to "murder" a project proposal by pointing out its flaws and weaknesses. This can be very useful in high-risk projects where there is little data from previous projects from which we can learn, or in situations where the environment has changed significantly since the development of the original scope of the project. Participants in a murder board session are encouraged to be aggressive and not hold back in their attempt to murder the project.
- **Qualitative Scoring Methods.** Scoring methods can take a variety of factors into account. These can range from simple checklists to complex weighted scoring systems. Scoring systems can assist staff with evaluating the relative merit of different projects while limiting political influence. Scoring models might survey a wide variety of experts and have them rate the project in terms of importance to the company or relative chance of success. Scoring methods will be examined in the next section of this chapter.
- **Economic Scoring Methods.** These methods assess the ability of the project to help the bottom line, either by increasing profits or reducing costs. These models often look at the cash flow that a project will generate after it is completed. The final section of this chapter examines economic models in more detail.
- **Constrained Optimization Methods.** Constrained Optimization Methods of project selection are mathematically intensive means of analyzing a series of projects and are not easily generalized (see http://en.wikipedia.org/wiki/Constrained_optimization). In project management, these methods can include:
    - Linear Programming
    - Dynamic Programming
    - Branch and Bound Algorithms
    - Integer Programming

  We might also refer to Constrained Optimization Methods as mathematical approaches to project selection. These methods are beyond the scope of this text, but students preparing to take PMI exams should know that if they see any type of programming or algorithms used for project selection, a Constrained Optimization Method is being used.

Of course, companies are not limited to just one methodology when choosing a project. They can, and typically do, use a combination of selection criteria.

Next, we will explore Qualitative Scoring Methods and Economic Scoring Methods in detail.

Section 2

Qualitative Scoring Methods

Qualitative Scoring Methods for project selection allow for the solicitation of input from many people about the projects up for review. There are two basic scoring methods: a simple checklist and a weighted scoring model.

Simple Checklist

Checklists are simple to use and understand. A set of selection criteria is generated and agreed upon by the major project stakeholders or sponsors. Those who study the field of management might refer to these criteria as Critical Success Factors (CSF). These can be measurable indicators of success. For example, “The project is likely to attract 3,000 new customers to our store in the next 12 months,” or “The project is likely to make a 30% return on investment.”

The selection criteria are organized into a checklist format, and then each project is reviewed and scored (see Table 5.3). Scoring can be done by a wide range of people inside and outside the organization. It is best to solicit input from a diverse group of subject matter experts. The project with the most boxes checked is deemed to be the best project.

<u>Advantages of a simple checklist:</u>

- Easy to understand and tally
- Multiple Criteria can be considered.
- Can be used to quickly gather input from a wide range of stakeholders.
- Easily changed to reflect management direction/policy
- Can be posted online to gather public input.

<u>Disadvantages of a simple checklist:</u>

- All criteria are treated equally and given the same weight.
- Criterial that are “must haves” are not separated from those that are “wants.”
- Easy to add too many non-important criteria to the checklist.
- Result of checklist is a relative score, not a go or no-go decision.

Table 5.3 A Simple Checklist for selecting a new sorting facility.

Criteria	Project A	Project B	Project C
Project aligns with our values and mission statement.	✓	✓	✓
Will not increase our carbon footprint.	✓		
Improves product delivery time by 20%.	✓	✓	
Cost to maintain over 10 years is not more than initial cost.			✓
Can be complete with in-house personal and resources.			✓
Design is aesthetically pleasing.	✓	✓	
TOTAL	4	3	3

Weighted Scoring

In order to make sure that a project meets an organization's "must have" criteria, a separate section containing these most important criteria can be added to the checklist. If the project fails to meet one or more of these factors then it will be rejected.

Weights can also be assigned to the CSFs to reflect the relative value of some factors over others. For example, in Table 5.3, equal weight was given to the looks of the design and to the cost of maintaining the facility. In the model shown in Table 5.4 below, weights are given to different criteria to reflect the relative importance of each to the organization.

Table 5.4 Weighted Scoring Model with Critical Factors and Weighted Scoring.

Critical Factors		Project A		Project B		Project C	
Should not cost more than $120,000		✓		✓		✓	
Compliance with all local governmental regulations.		✓		✓		✓	
Will not harm our company operations/image.		✓				✓	
Weighted Scoring	**Weight**	**Project A Score (0-3)**	**Project A Value**	**Project B Score (0-3)**	**Project B Value**	**Project C Score (0-3)**	**Project C Value**
Likely to produce spin-offs or other products	30	1	30	2	60	2	60
Likely to make $30,000 or more per year	80	2	160	2	160	1	80
Doesn't require outside consultants	30	2	60	2	60	1	30
Likely to gain us good press	10	0	0	2	20	2	20
Total			**250**		**300**		**190**

The weighted value for the project is calculated by multiplying the weight by the project score (0=very unlikely, 1= likely, 2= very likely). While Project B scores the highest, it fails to meet one of our Critical factors and would be rejected or revised so that it can meet this criterion.

Weighted scoring models have several significant advantages over simple checklists:

- Political games/sacred cows are exposed.
- Allows ranking of projects according to impact on key performance indicators for the company.

Section 3

Economic Scoring Methods

Economic scoring methods for project selection compare the costs and benefits of different projects. All of these models are objective as long as the inputs are not biased.

Payback Period

The payback period method simply calculates the amount of time it will take to recover the costs of the project, by means of either increased revenue or reduced operating costs. It is calculated by taking the entire cost of the project and dividing by the annual profit or cost savings.

$$\textbf{Payback} = \frac{\textbf{Cost of Project}}{\textbf{Annual Profit/Savings}}$$

For example, ABC Corporation is considering "Project Faster" to construct an automated package assembly and sorting facility. The project is estimated to cost $500,000. However, ABC Corporation estimates that it will save the company $125,000 per year in decreased labor costs. To calculate the payback for this project, we divide the cost of the facility by the estimated annual savings:

$$\textbf{Payback} = \frac{\$\textbf{500,000}}{\$\textbf{125,000}} = \textbf{4 years}$$

So, by making this investment now, we should be able to recover our investment in four years.

In the case where the estimated cash flow is not constant in every year, the payback is calculated by subtracting the cash flow for each year from the cost of the project.

For example, consider "Project Faster" but this time ABC Corporation estimates that it will save the company $156,000 in Year 1, $105,000 in Year 2, $100,000 in Year 3, $95,000 in Year 4, and $76,000 in Year 5 in decreased labor costs. To calculate the payback for this project, subtract the annual cash flows from the cost of the project, to yield a project balance (see Table 5.4).

In this example, the project has recovered all but $44,000 by the end of Year 4. The estimated cash flow in Year 5 is $76,000. So to calculate at what point in Year 5, we will have recovered our

Table 5.5 "Project Faster" payback example with uneven cash flows

	Cash flow from Profit/Savings	Project Balance
Year 1	$156,000.00	-$344,000.00
Year 2	$105,000.00	-$239,000.00
Year 3	$100,000.00	-$139,000.00
Year 4	$95,000.00	-$44,000.00
Year 5	$76,000.00	$32,000.00
Payback Period (percent of year)		4.58
Payback Period (Years and months)		4 years, 7 months
Payback Period (Years and months)		55 Months

costs, we can divide the project balance of $44,000 by $76,000 to find that it will take 0.58 of year 5 to payback the costs of the project from the project profits/savings. (to calculate in months, multiple 12 by .58: 6.95 months, round to 7 months).

While the payback is simple to calculate and understand, it doesn't account for the time value of money. Money today is worth more than it will be in the future; this concept will be explored in the next section. In order to account for the time value of money we can use either a Net Present Value calculation or an Internal Rate of Return calculation; both of these methods will be discussed shortly. Payback also doesn't reflect the size of the investment in the project, just the payback period.

Time Value of Money

Future dollars are always going to be worth less than current dollars. How much less depends on how well you can make your current dollars work for you.

To illustrate this concept, imagine you could have the choice of receiving $20,000 now, or $22,000 in three years. Which do you choose? If you receive the $20,000 now and are able to invest to in an account that will earn 5% annually, you will be better off to take the $20,000 now, and in three years you will have $23,152.50 (See Table 5.6). However if the offer was $20,000 now or $25,000 in three years, you would be better off taking the money three years from now.

Table 5.6 The Time Value of Money

	Principal	Interest Income (at 5%)	Total at End of Year
Year 1	$20,000.00	$1,000.00	$21,000.00
Year 2	$21,000.00	$1,050.00	$22,050.00
Year 3	$22,050.00	$1,102.50	$23,152.50

Net Present Value (NPV)

Net Present Value is one way to account for the time value of money in project selection. NPV uses a discount rate which reflects the decrease in value of money each year in the future. In addition to the discount rate, NPV is calculated over a set number of years that we are expecting our capital to be able to generate savings or profits for use.

This discount rate can also be considered the cost of capital dollars, which we may have to obtain via a bond, loan or equity sale. Regardless of how the capital for the project is obtained, the cost of capital will be calculated and known by the organizations in which projects are selected. A Net Present Value analysis uses the costs of capital or discount rate to calculate the value of future dollars in terms of what they would be worth today (called Present Value or PV).

Note: The acronym PV is used for Present Value when discussing NPV and project selection. However, the same acronym, PV, is also used in project management during earned value analysis to represent Planned Value! Be sure that you understand the context in which the acronym PV is being used if you are taking a PMI or other exam!.

The present value of earned or saved dollars for each time period is calculated using this formula:

$$\textbf{Present Value} = \frac{\mathbf{CF}_t}{(\mathbf{1}+r)^t}$$

- Where t is the time period for which we are calculating (for example, year 1, year 2, etc.). Note: We often will put our capital outlays in year 0.
- Where r is the discount rate.
- Where CF is the expected cash flow for the given year (net cash flow).

The formula for the NPV for the entire time period in which we are making calculations is:

$$\mathbf{NPV} = \sum_{\mathbf{t=0}}^{N} \frac{\mathbf{CF_t}}{(\mathbf{1}+r)^t}$$

- Where N is the total number of years for calculating NPV.
- Where t is the time period for which we are calculating (for example, year 1, year 2, etc.). Note: We often we will put our capital outlays in year 0.
- Where r is the discount rate.
- Where CF is the expected cash flow.

Consider the same example that was used in the discussion of payback. However, this time imagine that the $500,000 has to be financed by a bond which will incur interest and has fees associated with the bonding. In this case, our costs for the first year will be $500,000. For the years in which we will have cost savings, we will calculate what the value of those savings is in present dollars. In this case, we will use a 13% discount rate (cost of capital). As you can see from Table 5.7 on the next page, the perspective on our project shifts a little when we figure in the time value of money. **In this case, it will take 6 years to earn back our initial investment instead of the 4 years we calculated**

using the simple payback method. However, this is a more accurate from a financial viewpoint.

When calculating NPV for a project with a given time horizon, projects that **have a negative NPV should be rejected** and those with a positive NPV should be considered. When choosing between two or more projects that are mutually exclusive using NPV, t**he project with the highest positive NPV should be selected.**

Figure 5.2 "Project Future" Calculations: Simple Payback vs. NPV

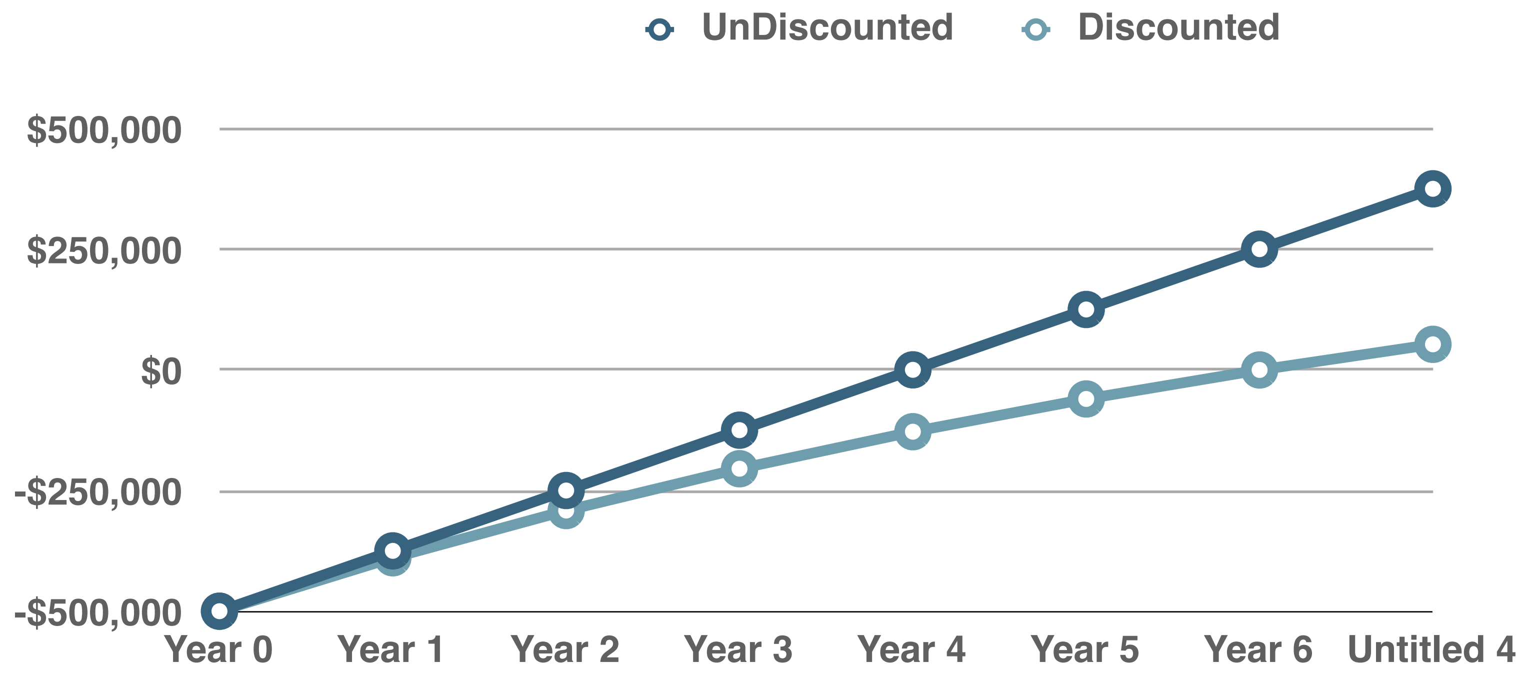


Table 5.7 Calculating the discounted value of money in the future for "Project Faster."

Year	Capital Costs	Annual Savings (Non Discounted)	Annual Savings (Discounted)	Cumulative present value of future cash flows
0	-$500,000.00	-$500,000.00	-$500,000.00	
1		$125,000.00	$110,619.47	-$389,380.53
2		$125,000.00	$97,893.34	-$291,487.20
3		$125,000.00	$86,631.27	-$204,855.93
4		$125,000.00	$76,664.84	-$128,191.08
5		$125,000.00	$67,844.99	-$60,346.09
6		$125,000.00	$60,039.82	-$306.28
7		$125,000.00	$53,132.58	$52,826.30

NPV Selection Example

The ABC Corporation is in the process of entering the nut distribution market and is considering two projects: Project Walnut and Project Filbert. The project selection committee has been tasked with providing an NPV analysis on these projects and has been given the following data.

Project Walnut

Capital Costs: $340,000
Annual Operating Costs: $30,000
Annual Operating Revenue: $90,000

Project Filbert

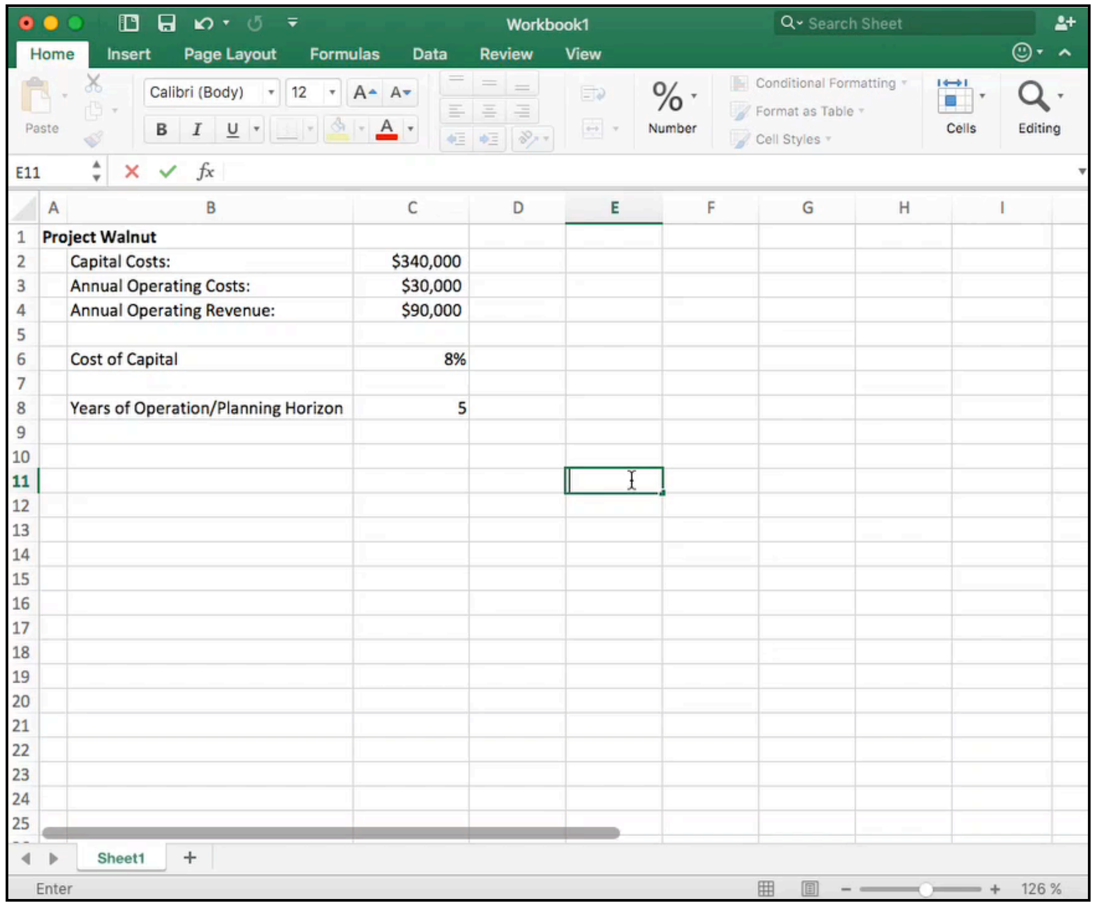
Capital Costs: $1,050,000
Annual Operating Costs: $390,000
Annual Operating Revenue: $800,000

ABC is looking at these projects over a five year span and the cost of capital at the ABC Corp is calculated at 8 percent. **Note:** We will need to account for the Annual Operating Costs by subtracting them from our Annual Operating Revenue.

As you can see from the tables on the next page, Project Filbert has a positive NPV after four years, where Project Walnut does not. Project Filbert is the clear winner in this case. You can see how these calculation are made with a spreadsheet program in Video 5.1.

Note: Programs like Excel, have build-in formulas for NPV but these formulas don't take into account the project costs (Year 0), so one must modify the formulas accordingly.

Video 5.1 NPV Calculations using Excel



Watch this video to learn how to make NPV calculation in Excel, using the formula presented in this chapter and Excel's built-in NPV formula. You can also view this video at: http://pmf.video/video19

Table 5.8 NPV for Project Walnut

Year	Capital Costs	Annual Operating Revenue	Annual Operating Costs	Net Revenue	Discounted Net Revenue	Cumulative present value of future cash flows
0	**-$340,000.00**			**-$340,000.00**	**-$340,000.00**	
1		$90,000.00	$30,000.00	$60,000.00	$55,555.56	**-$284,444.44**
2		$90,000.00	$30,000.00	$60,000.00	$51,440.33	**-$233,004.12**
3		$90,000.00	$30,000.00	$60,000.00	$47,629.93	**-$185,374.18**
4		$90,000.00	$30,000.00	$60,000.00	$44,101.79	**-$141,272.39**
5		$90,000.00	$30,000.00	$60,000.00	$40,834.99	**-$100,437.40**

Table 5.9 NPV for Project Filbert

Year	Capital Costs	Annual Operating Revenue	Annual Operating Costs	Net Revenue	Discounted Net Revenue	Cumulative present value of future cash flows
0	**-$1,050,000.00**			**-$1,050,000.00**	**-$1,050,000.00**	
1		$800,000.00	$390,000.00	$410,000.00	$379,629.63	**-$670,370.37**
2		$800,000.00	$390,000.00	$410,000.00	$351,508.92	**-$318,861.45**
3		$800,000.00	$390,000.00	$410,000.00	$325,471.22	**$6,609.76**
4		$800,000.00	$390,000.00	$410,000.00	$301,362.24	**$307,972.00**
5		$800,000.00	$390,000.00	$410,000.00	$279,039.11	**$587,011.12**

Internal Rate of Return (IRR)

Internal Rate of Return (IRR) is another measure that takes into account the future value of money, but rather than calculating a dollar amount, IRR is expressed as a percentage. This percentage represents the amount of return that a company will receive from an investment.

If project A has an IRR of 17% and Project B has a IRR of 30%, Project B would be considered the better investment. Using this measure, a higher number indicates a higher return and a better project.

However, realize that because IRR is expressed as a rate, rather than an amount, we don't know the magnitude of the return: Project A with a 17% return might yield a profit of three million dollars in present day value, while Project B with a 30% IRR might just yield a net profit of one hundred dollars in present day value.

When calculating IRR for a project, projects that **have a negative IRR should be rejected** and those with a positive IRR should be considered. When choosing between two or more projects that are mutually exclusive using IRR, t**he project with the highest positive IRR should be selected.**

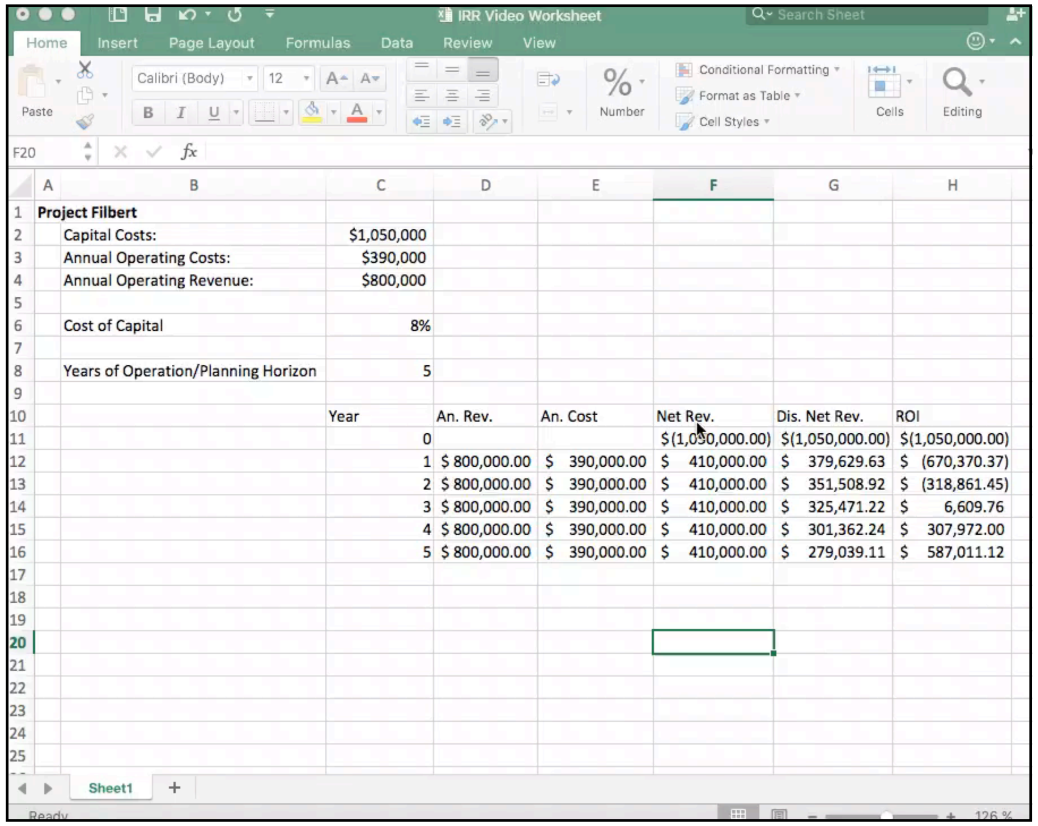
In order to calculate IRR percentage, we use a formula similar to the NPV formula and set the NPV equal to 0. We then solve for the return rate (r).

$$\mathbf{NPV} = \sum_{\mathbf{t=0}}^{N} \frac{\mathbf{CF_t}}{(\mathbf{1} + r)^t} = 0$$

- Where N is the total number of years for calculating IRR
- Where t is the time for which we are calculating (for example, year 1, year 2, etc.).
- Where r is the return rate.
- Where CF is the expected cash flow..

IRR is difficult to calculate mathematically. Instead a trial-and-error method is used to derive the rate. However, spreadsheet programs and financial calculators can make these “Solver” calculations easier to perform. See Video 5.2 on calculating IRR for an example.

Video 5.2 IRR Calculations using Excel



	A	B	C	D	E	F	G	H
1	Project Filbert							
2		Capital Costs:	$1,050,000					
3		Annual Operating Costs:	$390,000					
4		Annual Operating Revenue:	$800,000					
5								
6		Cost of Capital	8%					
7								
8		Years of Operation/Planning Horizon	5					
9								
10			Year	An. Rev.	An. Cost	Net Rev.	Dis. Net Rev.	ROI
11			0			$(1,050,000.00)	$(1,050,000.00)	$(1,050,000.00)
12			1	$ 800,000.00	$ 390,000.00	$ 410,000.00	$ 379,629.63	$ (670,370.37)
13			2	$ 800,000.00	$ 390,000.00	$ 410,000.00	$ 351,508.92	$ (318,861.45)
14			3	$ 800,000.00	$ 390,000.00	$ 410,000.00	$ 325,471.22	$ 6,609.76
15			4	$ 800,000.00	$ 390,000.00	$ 410,000.00	$ 301,362.24	$ 307,972.00
16			5	$ 800,000.00	$ 390,000.00	$ 410,000.00	$ 279,039.11	$ 587,011.12

Watch this video to learn how to make IRR calculations in Excel. You can also view this video at: http://pmf.video/video20

Benefit-Cost Ratio

Another way to look at the financial aspects of projects is with the Benefit-Cost Ratio (BCR) method. It will also factor in the time value of money. The formula for BCR is

$$\text{BCR} = \frac{\text{Discounted Value of Benefits}}{\text{Discounted Value of Costs}}$$

BCR can be evaluated this way:

- A BCR that is < 1 means that the costs are greater than the benefits.
- A BCR that is = 1 means that the project will break even
- A BCR that is > 1 means that the benefits are greater than the costs.

Benefit-Cost Ratios are often used on large public works projects, and have even been attempted in the context of analyzing public policy (for example, climate change). Quantifying benefits and costs can be a lengthy and difficult process and companies will have their own ways of arriving at those numbers.

When calculating BCR for a project, projects that **have a BCR less than one should be rejected** and those with a BCR of one or higher should be considered. When choosing between two or more projects that are mutually exclusive using BCR, t**he project with the highest BCR above one should be selected.**

Summary of Economic Scoring Methods:

- Payback shows the time it will take to recover our investment in the project, but doesn't account for the time value of money. **With payback calculations, a lower number is better.**
- Net Present Value (NPV) accounts for the time value of money, and is expressed as a dollar figure. **Higher values are better.**
- Internal Rate of Return (IRR) accounts for the time value of money, and is expressed as a percentage. **Higher percentages are better.** IRR doesn't express the magnitude (amount of dollars) of the project return.
- A Benefit-Cost Ratio accounts for the time value of money and is expressed as a ratio. **Higher numbers are better.** Like IRR, BCR doesn't express the magnitude (amount of dollars) of the project return.

Sidebar 5.1 Economic Scoring in Practice

Calculating Payback, NPV, IRR and BCR can require the consideration of many factors and is often done with assistance from our accounting departments. These calculations might also take into account salvage costs of equipment at the end of its life and other internal factors that might influence returns.

Chapter 6

Project Scope and Work Breakdown Structure

Chapter 6 Overview

Defining the work of a project is one of the first and most important steps in developing project plans. The project scope of work describes what work will need to be completed for the project. The project scope also provides a de facto definition of what work will not be done as part of a project.

The first section of this chapter discusses project and product scope, the project scope statement, scope creep, gold plating and other concepts regarding how work for a project is defined.

The second section discusses the work breakdown structure (WBS). A WBS is a hierarchical map or tree diagram representing all the deliverables and work for a project, and it is a useful tool for defining the project scope of work. Through a process of decomposition, a project is broken down into deliverables, sub-deliverables and work packages/activities and organized into a WBS. The creation of a WBS is the first stage in planning and scheduling the work for a project.

Learning Objectives:

- Understand the differences between project and product scope.
- Understand what is contained in a project scope statement and its value.
- Define scope creep and gold plating.
- Understand how cost and time are summarized in a WBS.
- Understand the how the process of decomposition is used to create a WBS
- Understand the difference between a deliverable and work package.
- Understand the WBS numbering system.

Section 1

Project Scope

The scope of a project represents, in the broadest sense, the work that will need to be completed for the project to finished successfully. A well-defined scope of work is a key asset for any project team.

Types of Scope

In project management, the term scope has two distinct uses — project scope and product scope.

- **Project scope** focuses on the work that will be done in order to complete the project.
- **Product scope** focuses on the features of the final product. This may or may not have an impact on the project scope.

For example, imagine a project that involves the construction of a one-story office building. The project scope would include the work that must be completed: a foundation must be laid, the exterior of the building needs to be covered with vinyl siding, etc.

A change to the planned color of the siding (product scope), would not have any impact on the project scope (the project manager would still have to make sure that someone with siding experience will be scheduled to install the siding). However, if the product scope changes to have brick siding, there will be a change to the project scope (now the project manager needs to hire someone with bricklaying skills, the walls may need to be changed to provide anchors for the bricks, etc.).

The project manager is mainly concerned with project scope. The more well defined the project scope is at the initiation of a project, the easier it is for a project manager to develop the project plans and execute those plans.

The Project Scope Statement

The project scope statement is a formal document that outlines the purpose and parameters of the project and is used to develop project management plans. This may also be referred to as the statement of work (SOW). The project scope statement may include:

- A list of the high level project requirements, activities and goals. These activities and goals should be described in a way that sets clear boundaries for the work that will need to be performed.
- A list of major deliverables for the project.
- A description of the business justification/rationale for the project, explaining what it will do for the organization, and why was it picked over other possible projects.
- A description of any project constraints in terms of time and cost.
- A timeline with major milestones.

Sidebar 6.1 Scope in Agile Projects

In agile projects, scope is represented by user stories and the backlogs associated with each iteration or release. In agile, changes to the scope are welcomed if they will increase value to customers, whereas in more traditional projects later changes to scope are discouraged.

- A list of any assumptions that have been made about the project (that certain assistance will be available, etc.).
- A detailed work breakdown structure and WBS dictionary (see next section for information about how thses are created). PMI considers this a must have item for a project scope statement.
- Information about the acceptance criteria for the project.
- Cost estimates for the project and information about hwo the cost estimates were made.

The project scope statement may also include a section with information about the activities or deliverables that are specifically outside of the scope of the project.

Scope Creep

Scope creep, also called feature creep, function creep or requirement creep, is the gradual expansion of scope as the project is executed. Scope creep can be very harmful to a project, eventually causing delays, cost overruns, and bad feelings between the customer and project team. In a project where the scope of work is poorly defined, the chance of scope creep is increased.

Scope creep often starts with a request for a small addition or small amount of extra work that is outside the project scope. Resisting the urge to "go the extra mile" for the customer is difficult, especially for new team members. By making that first small addition, a precedent has been set that the project team will regularly take on work that is beyond the scope of the project.

Preventing Scope Creep

There are several ways that project managers can reduce the chance of scope creep:

- Have a well defined scope of work and detailed work breakdown structure. Make sure that everyone on the project is familiar with these documents.
- Implement a change control system so that all changes to scope are reviewed and considered. This system should consider the impact a requested change will have on schedule, budget, and the project's other activities.
- Maintain good communication so that all stakeholders understand the cost of adding new features to the project scope.

Gold Plating

Gold plating is a type of scope creep that occurs when people working on the project add features, upgrade the materials, or add work to the project without the customer requesting the upgrade or extra work.

Some members of the project team may incorrectly think that, if a project is under budget or ahead of schedule, is it appropriate to reinvest that time or money into upgrading some aspect of the project to impress the customer or increase the value to the project. Such thinking is common when the project team doesn't understand the difference between quality and grade:

- Quality in project management is defined as meeting the specifications of the project. Any deviations from the project specifications reduce the quality of a project.
- Grade in project management is the type of material that is used in a project.

For example, assume that a project involves building a room in which the walls are specified to be covered in drywall and painted white. The project manager decides that the project budget is big enough to allow him to cover the walls with hardwood paneling, making the room look much more impressive. PMI and most project managers would consider this to be a low quality result. Hardwood is not higher quality, just a higher grade of wall covering. The project specifications called for painted drywall. The project manager deviated from the specification and didn't deliver what the customer requested.

Also consider that the customer may not want an impressive looking room and might have rather had money left over at the end of the project to put toward the next project.

Section 2

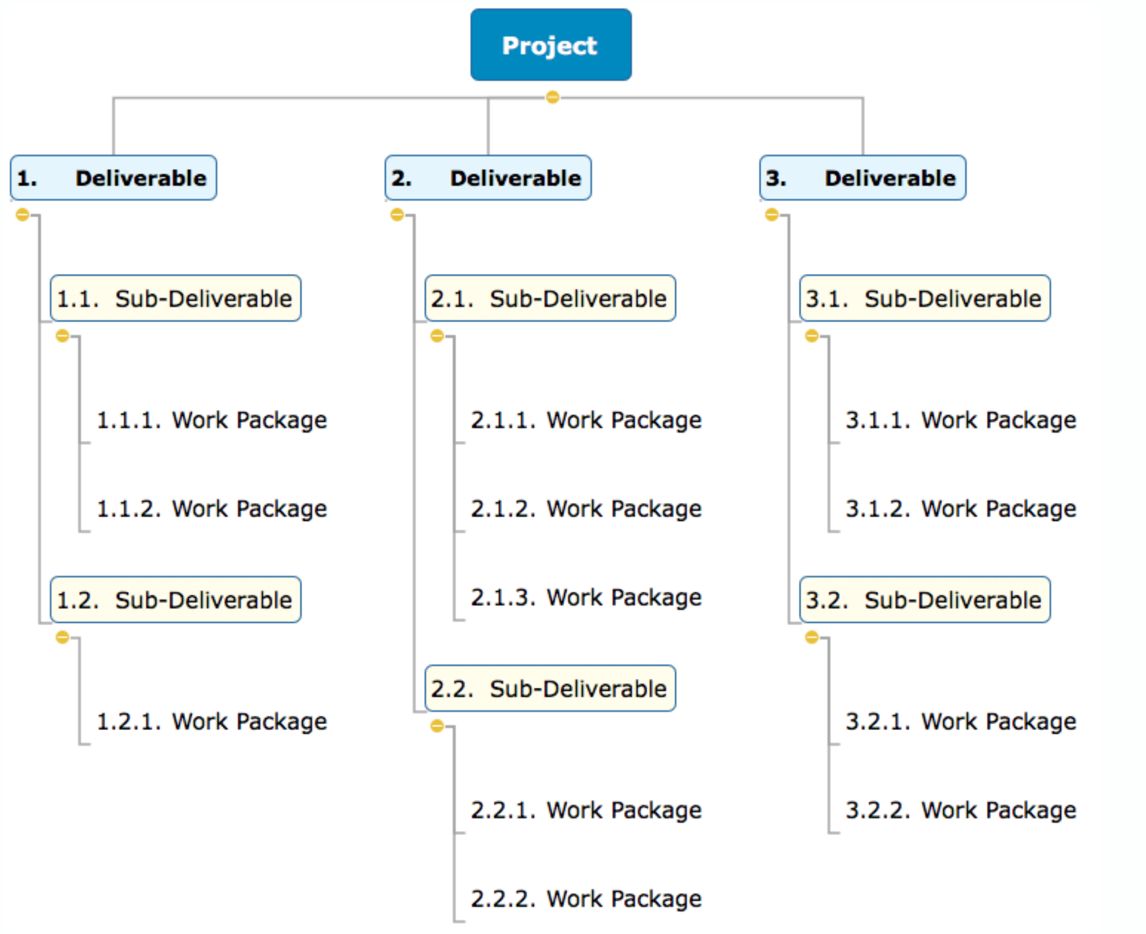
The Work Breakdown Structure

The Work Breakdown Structure (WBS) is a hierarchical outline of all the deliverables involved in completing a project. The WBS is part of a project scope statement. The creation of a WBS is one of the first steps in organizing and scheduling the work for a project.

Work Breakdown Structure (WBS)

The WBS is a breakdown of a project into sub-deliverables and eventually work packages. Each level of the WBS, represents more detailed information about a project. Figure 6.1 shows how the project is broken down into major deliverables and then into sub-deliverables and work packages.

Figure 6.1 A Work BreakDown Structure



The WBS is an outline that shows how the deliverables, sub-deliverables and work packages relate to the final project.

Deliverables vs. Work Packages

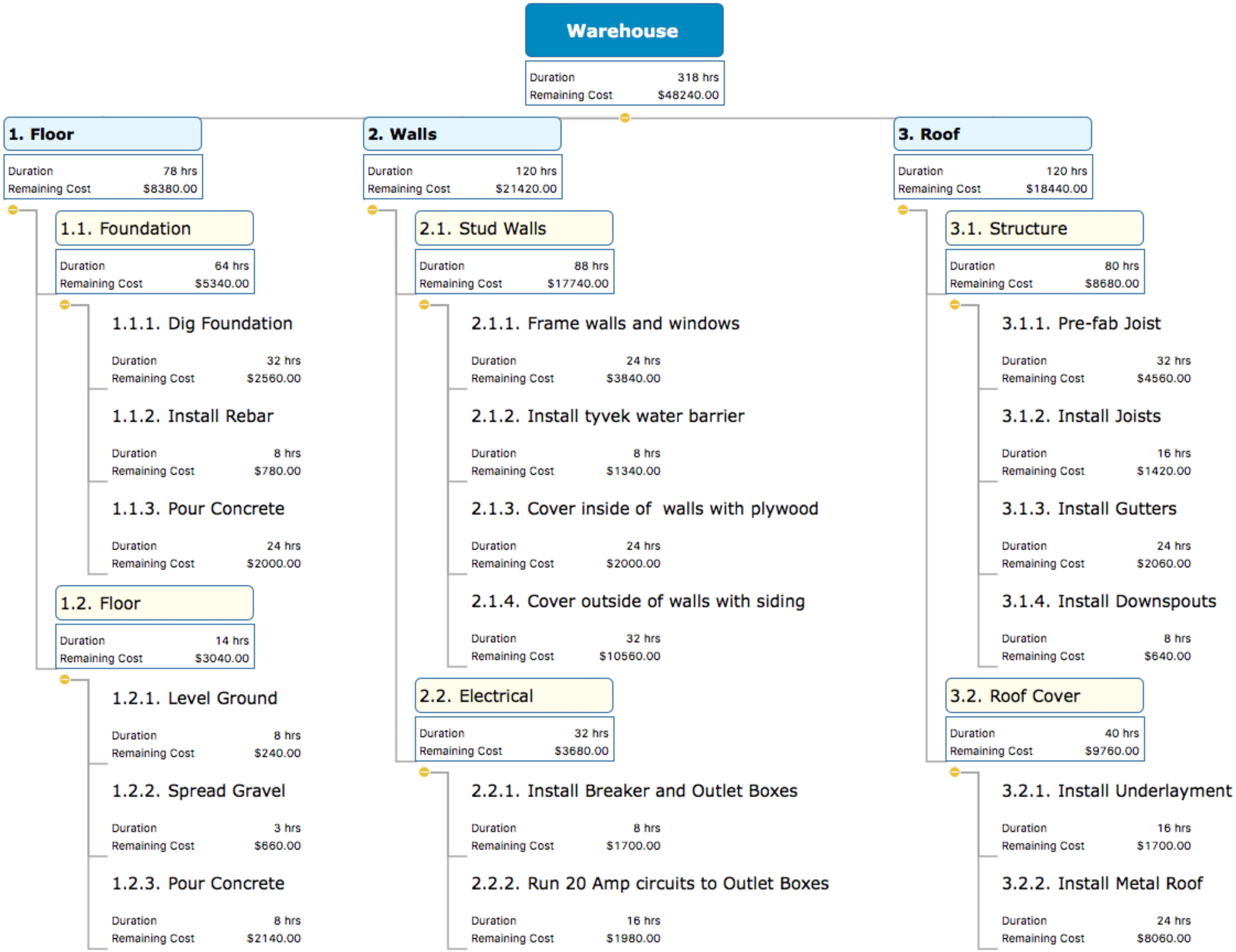
Deliverables and sub-deliverables are things such as physical objects, software code, or events. In a WBS, deliverables and sub-deliverables are represented by nouns (see Figure 6.2).

Work packages are assignable units of work that will be performed to create the related deliverable. A work package can be assigned to one particular project team member, one outside contractor, or another team. The work packages maybe further broken down into activities or tasks by the project team or the experts who will perform that work (see WBS dictionary later in this section). Work packages are action oriented and will be represented by phrases containing verbs (see Figure 6.2).

The cost of a deliverable is the sum of all of its related sub-deliverables. In Figure 6.2, the cost of the Walls deliverable is the sum of the Stud Walls and the Electrical sub-deliverables ($17,740 + $3,680 = $21,420). Likewise, the cost of a sub-deliverable is a summary of all of the work packages that must be completed to complete the sub-deliverable. In Figure 6.2, the cost and duration of the Stud Walls deliverable is a sum of all the related work packages ($3,840 + $1,340 + $2,000 +$10,560 = $17,740; 24hrs + 8hrs + 24hrs + 32hrs = 88hrs).

Since the WBS provides a natural way to summarize (or “rollup") the costs and labor involved for various sub deliverables, it also provides the project team with the information need to determine

Figure 6.2 WBS for New Warehouse Project



whether some deliverables would be better performed by an outside specialist who could deliver the item or service more cost-effectively. In the example in Figure 6.2, if the project manager can find a roofing contractor that complete the roof in less than 15 days (120 hours) and for less than $18,440, then it would be better to outsource that part of the project.

Note that work packages are independent of each other in a WBS, and do not summarize or include the work from other work packages. Work packages are the lowest level of the WBS.

WBS Numbering

Project managers use the WBS during project execution to track the status of deliverables and work packages. The items in a WBS are numbered so it is easy to understand the deliverable, or sub-deliverable, to which any particular work package is related. Notice that in Figure 6.2 the Install Metal Roof item is numbered 3.2.2, so it is easy to see that this work package is related to the third major deliverable (Roof: **3**.), and the second sub-deliverable (Roof Cover: 3.**2**.) and that is it the second work package for creation of the roof covering (3.2.**2**).

This numbering system allows for easy reference and filtering. For example, an electrician working on the Warehouse project only needs to receive details and updates that are related to work packages that start with 2.2 (the Electrical sub-deliverable).

Decomposition

Decomposition is the process used to break the project scope of work into the deliverables, sub-deliverables, and work packages involved in completing the project.

The process of decomposition begins with identifying the highest level deliverables. These deliverables are then broken into sub-deliverables. Many layers of sub-deliverables may be needed for a project. A general rule of thumb is that if the WBS has more than 5 layers of sub-deliverables, the project team should reassess and try to simplify the WBS structure (often by changing the way higher level deliverables are grouped and broken down).

Once the lowest level of deliverable has been reached, the next step is to break the sub-deliverables into work packages. The work packages describe the work that needs to be done to create the sub-deliverable. Remember that work packages typically contain verbs, and can be assigned to a person, team or contractor.

Once the project team has drafted the WBS, they should ask themselves: "if all the work packages were completed, and all the deliverables in this WBS were delivered, would the project be complete?" If the answer is no, then pieces of the WBS are still missing. If the answer is yes, then the project team can move on to creating the WBS dictionary, getting bottom-up estimates on time and resource requirements, and planning how to schedule the work.

The WBS Dictionary

The WBS dictionary provides detailed documentation about each work package including;

- Who is responsible for completing the work package?
- What resources will be needed to complete the work package?
- What deliverable(s) is the work package contributing to?
- What deadlines or milestones are associated with this work package?
- What are the acceptance criteria for this work package?

When the WBS is created, not all of the information about the work packages is known (for example, the estimates for labor and material costs). Remember from Chapter One that the planning process continues throughout the execution of the project. As a result, the WBS dictionary is a “living document” that will be augmented, edited and updated as the project moves forward. Figure 6.3 is an example of a WBS Dictionary entry; note that several items will be added later in the planning process.

The WBS and Project Schedule

One important item to note about the WBS: it doesn’t represent the order in which the work will actually be performed. The work packages and related activities will be scheduled when the project team creates a network diagram of all the work packages/activities and schedules the resources needed to complete those work packages.

Figure 6.3 A WBS Dictionary Template

Project: Warehouse	Last Modified: October 1st, 2016
Work Package Name: Prefab Joist	Work Package ID: 3.1.1
Description of Work: The joists and struts for the warehouse roof will be prefabricated offsite and then brought to the job site for installation. Wood 2x6s will be used for creation of the joists.	
Milestones 1. Delivery of all raw materials 2. Complete pre-fabrication of joists 3. Delivery to work site.	Due Dates: TBD: Will be Completed after Resource Estimation and Scheduling.

ID	Activity	Resource	Labor			Material			Total Cost
			Hours	Rate	Total	Units	Cost	Total	

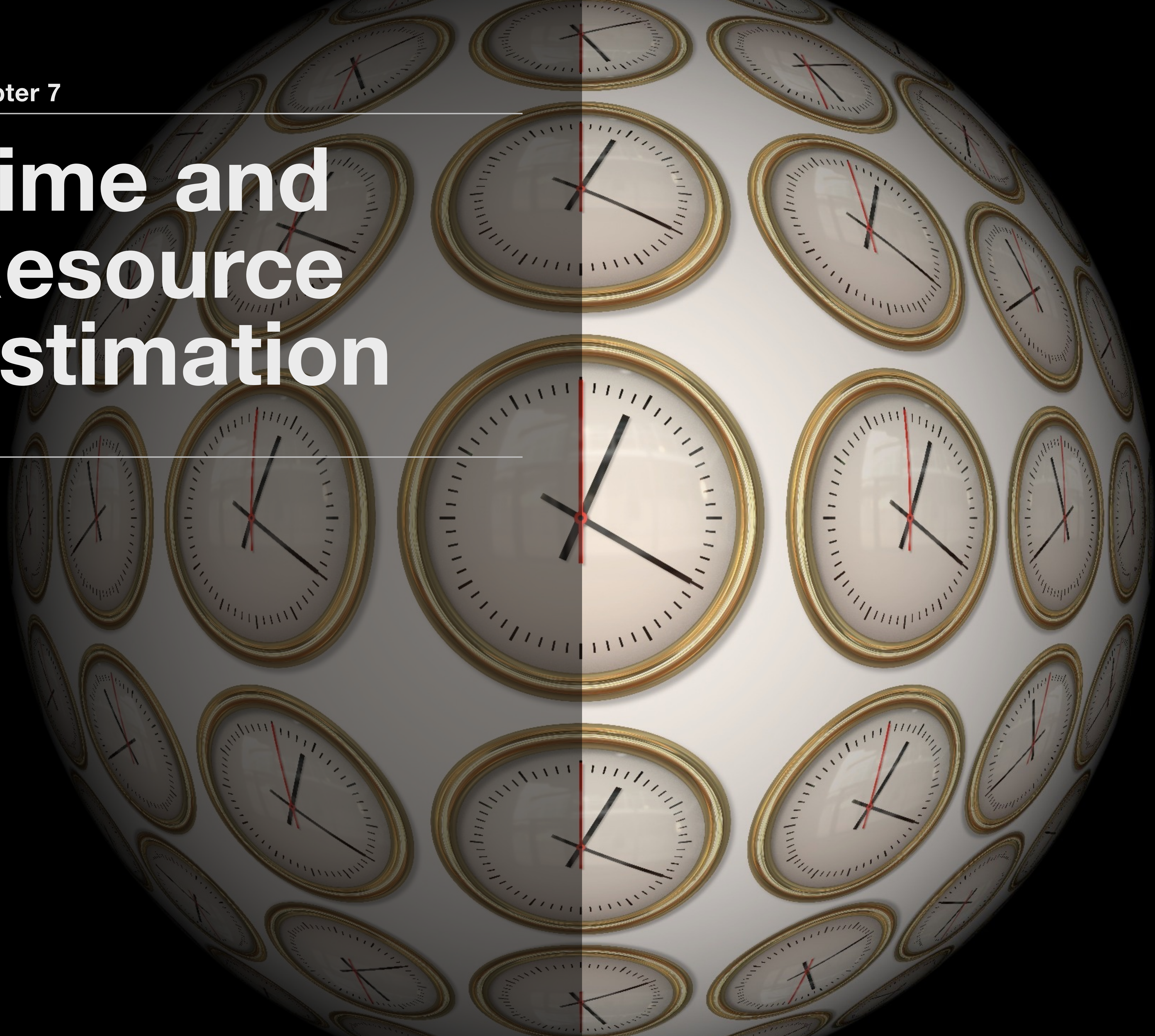
TBD: Will be Completed after Resource Estimation and Scheduling.

Acceptance Criteria: Visual Inspection at Job Site
Technical Information:
Contact Information: Jim Crews, 555-1251

In this example the Due Dates and detailed information about activities and costs will be added to the WBS dictionary later in the project planning process.

Chapter 7

Time and Resource Estimation



Chapter 7 Overview

Correct estimation of the time and resources required for a project is vital to understanding the commitment needed to successfully complete a project. Poor estimates can lead to project failures and can be very costly for an organization.

The first section in this chapter covers the major types of top-down and bottom-up estimation techniques.

Top-down estimates are used to provide rough estimates of the time and resources required for a project. This allows the organization to determine the resources and funding that will be needed if the project goes forward. Top-down estimation methods include:

- Analogous Estimating
- Parametric Estimating
- Learning Curves
- Function Point Analysis

Bottom-up estimates provide more detailed and accurate estimates. These are often generated after a project has been chartered and the project team is making detailed project plans. Bottom-up estimation methods include:

- Single point estimates
- Three-point estimates
- Multiple estimators: simple average
- Multiple estimators: T_e average
- Multiple estimators: Delphi technique.

The second section of this chapter explains how three-point estimates can be used to conduct a Program Evaluation and Review Technique (PERT) analysis to determine the probability that an activity or project will be completed within a given time frame.

Learning Objectives:

- Understand top-down estimation methods.
- Be able to calculate parametric estimates.
- Be able to calculate learning curves and apply them.
- Understand bottom-up estimation methods.
- Be able to calculate T_e given an activity's optimistic (a), most likely (m), and pessimistic (b) estimates.
- Understand how a PERT analysis is conducted.

Section 1

Time and Resource Estimation

Project plans are based on estimates of the time and materials required; estimates are the foundation for a project's success. Estimates for the time required to complete various activities are especially critical and hard to accurately determine. There are several methods for providing quick estimates (top-down or macro techniques), and for arriving at more precise estimates (bottom-up or micro techniques). This section discusses some basic principles for creating good estimates and the most common estimation methods.

Making Estimates

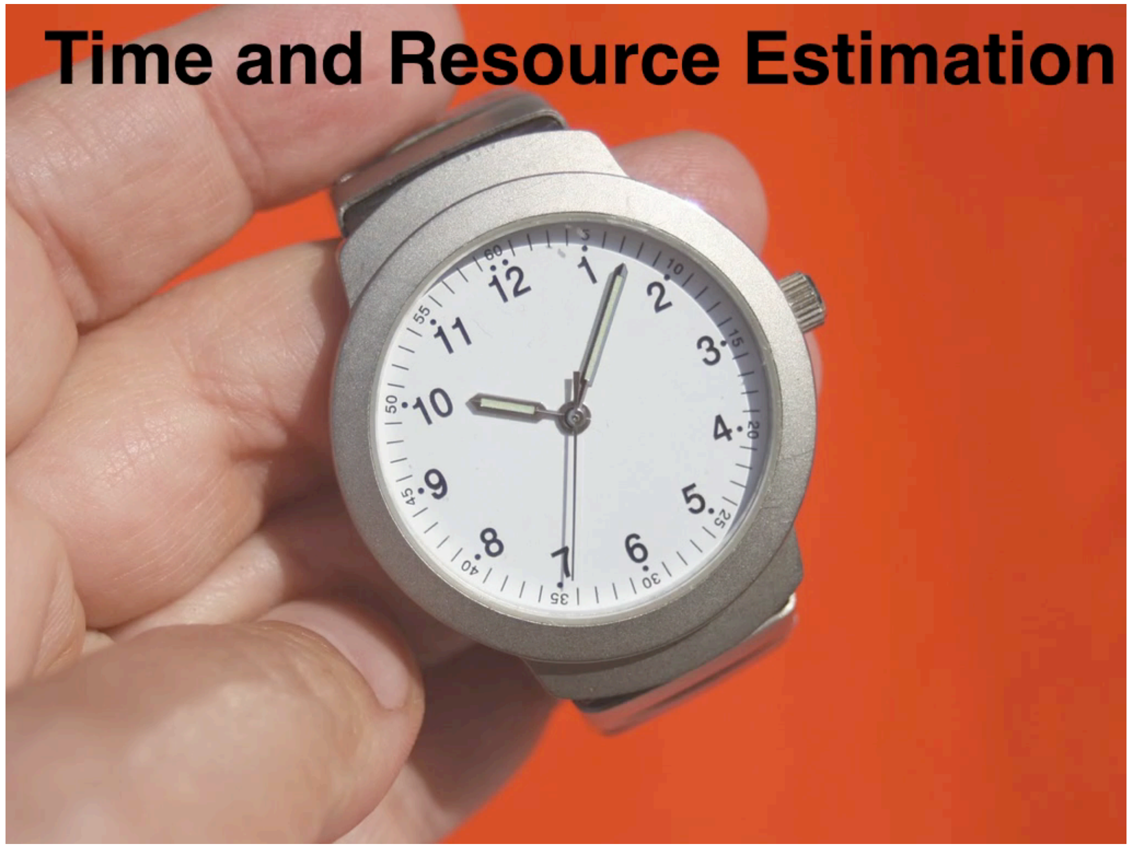
Estimates have a huge influence on a project and are a large source of project risk. Watch Video 7.1 to learn about how estimates are used for project planning.

Top-down, or macro, estimation methods are used to determine if a project is feasible, to calculate funding requirements, and to determine the resources needed to complete a project. These methods are not extremely accurate but provide a relatively fast way to make an estimate of the time and costs required for a project.

Bottom-up, or micro, estimation methods are used to provide a detailed, and more accurate, estimate and are usually derived from the detailed list of work packages or activities found in the work-breakdown structure.

As Video 7.1 mentions, all estimates contain risk. If estimates are too low, then a project will take more time and money to complete than what was budgeted. Obviously a bad situation. If estimates are too high, then a project will take less time and money that originally estimated. This might seem to be a desirable situation, but good project managers will realize that estimates that are too high will cause an organization to over-allocate resources to a project, thereby preventing other projects from being pursued due to organizational resource shortages.

Video 7.1 Project Estimates



You can also view this video at: http://pmf.video/video35

Therefore, it is important to have the most accurate estimates possible. The project team needs to understand the value of accurate estimates and avoid the natural human tendency to pad estimates; in other words no “Scotty Factors” allowed (see Sidebar 7.1). Once unbiased estimates for a project have been generated, the project manager can calculate what time buffers and budgetary reserves should be added to the project plan to deal with uncertainty (see the section on PERT Analysis later in this chapter).

Sidebar 7.1 The Scotty Factor

The original source for this term was the movie Star Trek III. Kirk asks "Mr. Scott, have you always multiplied your repair estimates by a factor of four?" To which Scotty replies, "Certainly, Sir. How else can I keep my reputation as a miracle worker?"

In Star Trek: The Next Generation, Scotty is horrified to learn that Geordie has given accurate estimates to the captain. "How are ye going to get a reputation as a miracle worker?" he asks the somewhat confused Geordie.

—From http://c2.com/cgi/wiki?ScottyFactor.

While good for science fiction, Scotty factors are extremely poor for project management. Any and all padding should be discouraged by project managers and the project team.

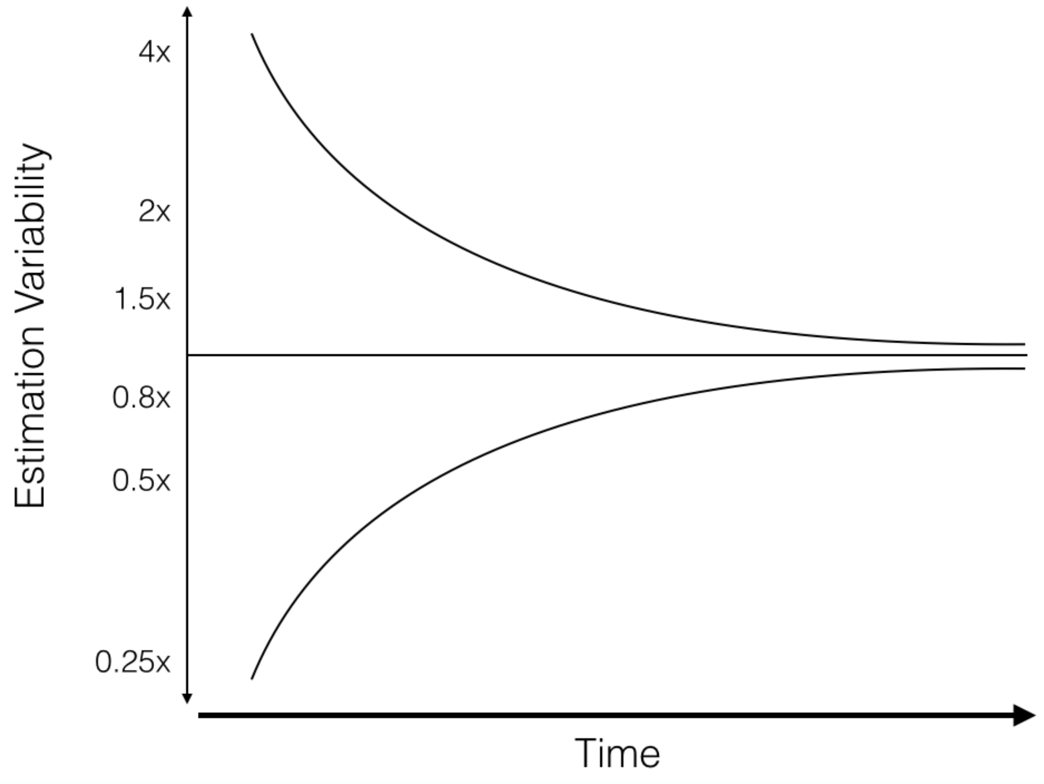
Accuracy of Estimates

Prior to project authorization, estimates for project costs need to be given, but these estimates can be rough estimates. As the project progresses, more definitive estimates will be needed and can be generated.

PMI defines the following ranges for estimates:

- **Rough Order of Magnitude (ROM).** ROM estimates are made at the initiation of the project and can be +/- 50 percent from the actual or final cost.
- **Budget Estimate.** Budget estimates are used in project planning and can be within a range from -10 to +25 percent from the actual or final cost.
- **Definitive Estimate**. Definitive estimates are generated as the project progresses and the variability of the estimate is reduced (see Figure 7.1). Definitive estimates are within a range from -5 to +10 percent from the actual or final cost.

Figure 7.1 Estimation Variability over Time



Estimates contain a high degree of variability at the inception of a project, and that variability decreases as the project is defined and moves toward completion.

Top Down (Macro) Estimation Techniques

Top-down, or macro, estimation methods allow for a quick estimate of project costs based on historical information.

Analogous Estimating

Analogous estimating uses information from a previous project to estimate the cost of completing a similar project in the future. This provides a quick estimate, but should be used with caution. Analogous estimating only works when comparing projects that are similar in scope and will be completed in similar conditions.

For example, a small IT business developed a website for a local restaurant for which they charged $4000. Another restaurant approaches the IT firm and asks for a rough cost estimate for a similar site. The IT firm can tell the second restaurant that such work will cost approximately $4000. Of course, the caveat is that this second website will have a similar number of pages, functions, and graffics as the first site.

The advantage of analogous estimating is that it allows for a very quick estimate to be provided for a customer. If in the example above, the second restaurant had only budgeted $200 for a website, they would have quickly determined that they have not budgeted enough, and the IT firm would be able to quickly determine that this is not a serious customer. However, if the second restaurant is okay with this approximate price, the IT firm can work with the restauranteur to develop a detailed cost proposal.

Analogous estimating, is not accurate if:

- The projects differ in scope.
- There is a difference in the conditions under which the work will be performed.
- There is a difference in the cost of resources (materials, labor).

Parametric Estimating

Parametric estimates, also called the ratio method, uses historical information or industry benchmarks as the basis for making an estimate. Parametric estimates are made by multiplying the size of a project by an established cost per unit.

For example, industry data is available for the per square foot construction cost for many types of buildings. An architect can use this information to make a parametric estimate by multiplying the cost per square foot by the size of any new building being considered. If an organization wants to build a new hospital using union labor, a rough estimate of the construction cost can be calculated using the information in Table 7.1: 20,000 ft^2 clinic X \$318.95/ft^2 = \$6,379,000. The organization can then use this estimate as an approximate cost and start securing the money for the project. Once the funding is secured, an architect can develop a complete plan and produce a more accurate project budget, using a bottom-up estimation method.

Table 7.1 Hospital construction costs

Cost Estimate (Union Labor)	Cost per Square Foot
Labor and Materials	\$234.09
Contractor Fees (GC, Overhead, Profit)	\$58.52
Architectural Fees	\$26.34
Total Building Cost (per Square foot)	**\$318.95**

Cost Estimate (Open Shop)	Cost per Square Foot
Labor and Materials	\$217.51
Contractor Fees (GC, Overhead, Profit)	\$54.38
Architectural Fees	\$24.47
Total Building Cost (per Square foot)	**\$296.36**

Data from Reed Construction (http://www.cmdgroup.com/) 2014.

Learning Curves

Projects that require an activity to be repeated several times throughout the project will benefit from a so-called learning curve. Learning curves, also known as improvement curves or experience curves, are important when labor is one of our main resources.

Consider a large construction project for a new highway. The first hundred feet of highway may be fairly slow to complete. But as workers become more experienced, and figure out better ways to organize their work, the time required to construct the next one hundred feet of new highway will be less.

Learning curves were first observed in aircraft production and are also used heavily in operations management. Each time production doubles, a learning rate can be calculated. See Table 7.2 for the calculation of a learning curve. When output doubles, from the first screen installed to the second, a learning rate is calculated. Another learning rate is calculated when the output doubles from the second screen installed to the fourth, and so on. The average learning curve can then be calculated. Later, if this company is contracted to install projector screens as part of a project, they can use this learning curve in their labor estimates.

There is a limit to the improvement of a learning curve. Eventually, the learning curve will "bottom out" and no more improvement gains can be achieved.

Table 7.2 Learning curve calculation

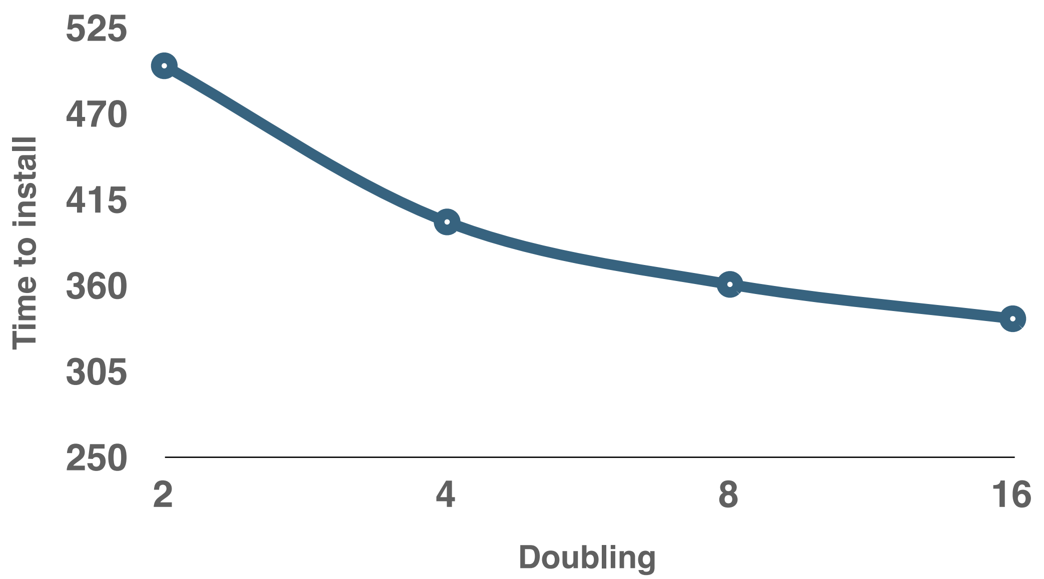
Number of screens installed	Time to install projector screen	Learning Rate
1	500	
2	440	88.0%
3	420	
4	400	90.9%
5	390	
6	380	
7	370	
8	360	90.0%
9	355	
10	350	
11	345	
12	344	
13	342	
14	340	
15	339	
16	338	93.9%
	Average	90.7%

Each time production is doubled, the learning rate for that doubling is calculated: (screen 2 time/screen1 time), (screen 4 time/screen 2 time), (screen 8 time/screen 4 time), and (screen 16 time/screen 8 time).

However, there are several things that can be done to extend and improve the slope of a learning curve:

- Incentivize workers to improve the processes they are using to complete their tasks. These incentives are “built in” for companies that are employee owned, where employees share in the reward if profits increase.
- Make investments in new technology and equipment.
- Invest in training and education for new workers, so they are not “learning on the job."
- Give workers the flexibility to make changes to how materials are sourced, delivered, and organized.

Figure 7.2 Learning



Data from Table 7.1 shown on a graph. Notice that the longer production occurs, the less improvement from one doubling to the next.

- Re-engineer the deliverables so they are easier to produce.

Learning curves usually hold if the work is continuous. If there is a break in the work, gains in productivity when work resumes will not be as great as if the work had continued uninterrupted. For more information on learning curves, consult *Learning Curve Analysis* at http://pmf.video/link5 .

Function Point Analysis

Function point analysis is used to estimate time and labor costs in very large software projects. Function point analysis is very similar to parametric estimating.

A function point is a measure of the functionality that is programmed into an information system and provide a measurement of a software project's size. Function points can be operations such as making a query to a database, designing an interface to collect information, or processing information. In a function point analysis, the number of each type of operation is collected and the complexity those operations is assessed (See Table 7.3). The number of function points in each category is multiplied by the complexity of those operations, and summed to arrive at a total number of function points.

Table 7.3 Function Points for a Software Project.

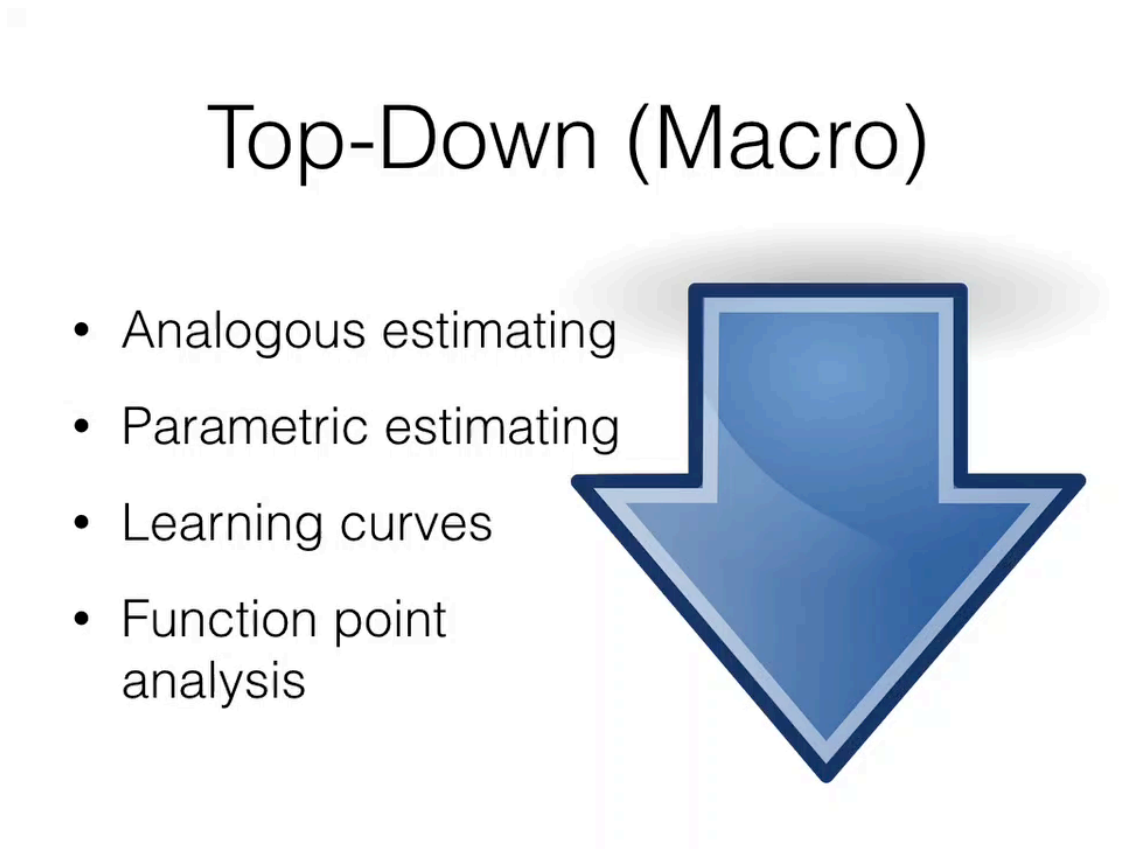
Category	Number	Complexity	Sub-Total
External Inputs	3	3	9
External Outputs	4	7	28
External Queries	2	4	8
Internal Logic Files	5	7	35
		TOTAL FUNCTION POINTS	**80**

In the example in Table 7.3, if one assumes that one function point is an equivalent of eight hours of work in the C++ computer programming language, then the project will take 640 hours to complete (80 function points X 8 Hours = 640 Hours).

Top-Down Summary

Watch Video 7.2 for a summary of the top-down estimation techniques that were just covered.

Video 7.2 Summary of top down estimation



You can also view this video at: http://pmf.video/video36

Bottom Up (Micro) Estimation Techniques

Bottom up, or micro, estimation techniques are used when the project is approved or is very likely to be approved. Bottom up estimation techniques generate estimates for individual work packages or sub-deliverables, which are then summarized to reflect total costs. Bottom up estimates are more accurate, detailed and take more time to generate. Instead of relying on historical information, bottom-up estimates rely on people with experience who can provide time and cost estimates for a particular work package or sub-deliverable.

These basic guidelines should be followed when generating bottom up estimates:

- Have people familiar with the work make the estimate.
- If possible use several people to make estimates.
- Estimates should be based on normal conditions and a normal level of resources.
- Estimates should not make allowances for contingencies. The project manager or team will add buffer times and contingency funds to the project after estimates are collected and analyzed.

Single point estimate

Single point estimation is an estimate obtained from just one estimator. This can work well with experienced estimators and work packages that are straight forward. Single point estimates are quick to generate and summarize in a project plan. The risk with single point estimates is that the estimator will overlook some aspect of the work and inadvertently provide an inaccurate estimate.

Figure 7.3 Single point estimate

A single point estimate relies on one expert to provide an estimate.

Three-point estimate

Instead of asking an estimator for just one estimate, a three-points estimate asks the estimator to provide three time estimates for each activity:

- An optimistic time estimate (if all goes well, what is the shortest time period one could realistically expect for the completion of this activity?). This will be designated in calculations as **a**.
- The most likely time estimate (if all goes normally, what is the average time one would expect it would take for an activity to be completed?). This will be designated in calculations as **m**.
- A pessimistic time time estimate (if work goes poorly, what is the longest time period one could realistically expect for the completion of this activity). This will be designated in calculations as **b**.

Figure 7.4 Three point estimate

Estimators provide us with optimistic (a), most likely (m), and pessimistic (b) estimates for activities.

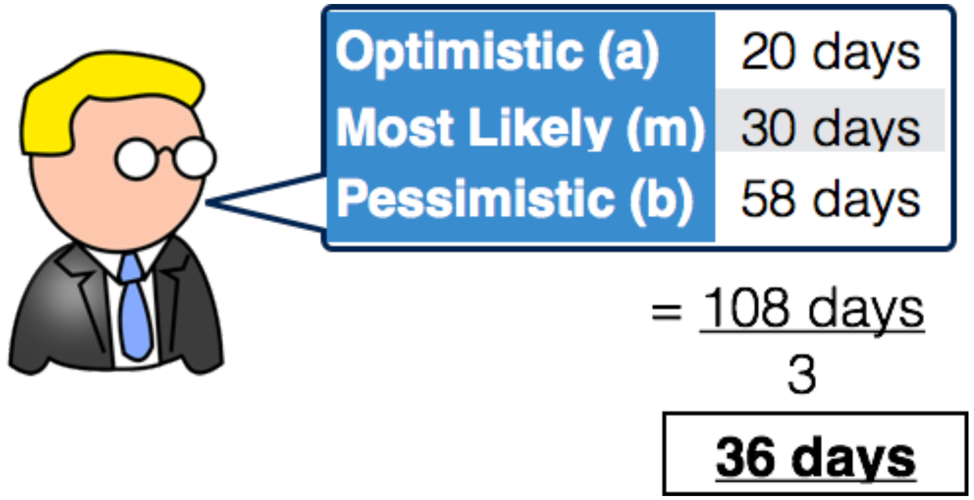
These three estimates can be used as inputs to calculate an estimated time for the activity or work package to be completed, either through a simple average or through a weighted average know as T_e.

Simple Average

The estimate for the optimistic, most likely and pessimistic time periods can be used to calculate a simple average.

$$\mathbf{AveTime} = \frac{\mathbf{a + m + b}}{\mathbf{3}}$$

Figure 7.5 Simple Average (Triangular Distribution)



A simple average of these values will provide us with an average time for completion of 36 days, but this calculation doesn't properly weight the most likely estimate.

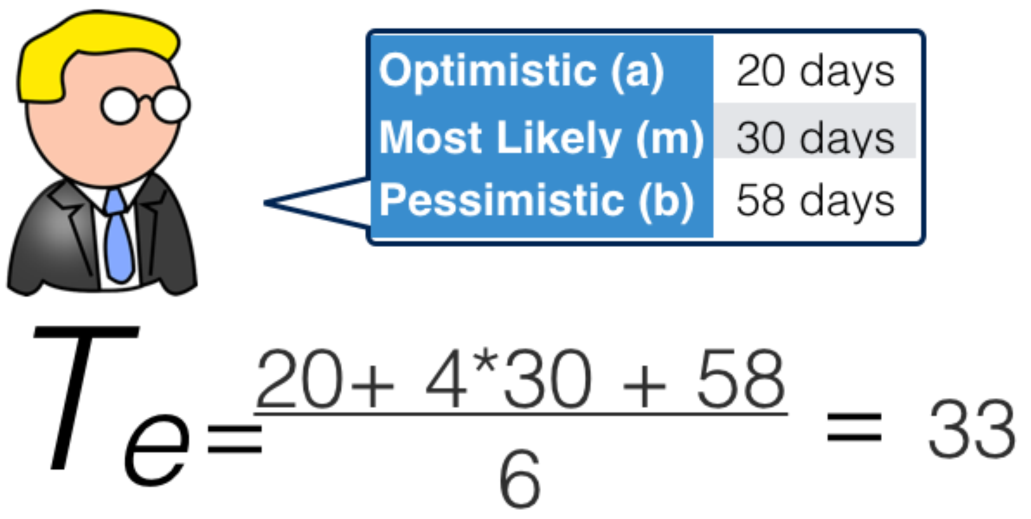
This simple average gives equal weight to all three time estimates (See Figure 7.4). However, for increased accuracy the most likely estimate (m) should receive more weight in these calculations since it is closer to the likely completion date.

T_e

T_e is a weighted average that weights the most likely estimate more heavily. The weighted average activity time is computed by the formula below. This can be adjusted by the project manager for different circumstances, but this is the generally accepted formula.

$$T_e = \frac{a + 4m + b}{6}$$

Figure 7.6 T_e Calculation of expected activity duration.



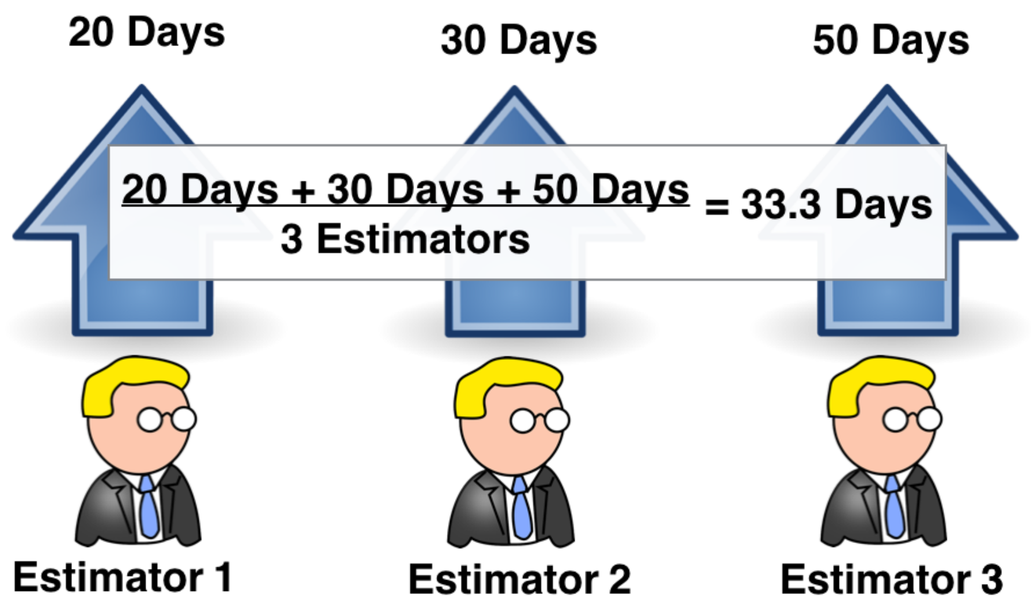
This formula for calculating activity duration properly weights the most likely estimate.

Three point estimates can be further analyzed to assess the variability (risk) in a project's estimates. The probably of completing the project in the estimated time (T_e) can be calculated (see the next section on PERT Analysis).

Multiple Estimators: Simple Average

Instead of relying on one estimator, the project manager can solicit estimates from multiple estimators and then average those values to arrive at an estimate (See Figure 7.7).

Figure 7.7 Multiple Estimators Simple Average



Multiple Estimators: T_e Average

A project manager can also obtain three point estimates from multiple estimators and calculate a weighted average using those values as well (see Table 7.4).

Multiple Estimators: Delphi technique

Alternatively, a project manager can solicit estimates from multiple estimators and then try to get those estimators to come to a consensus using the Delphi technique.

The Delphi technique is a method used to drive a group of experts to reach a consensus or at least come to a closer agreement. This method was originally designed in the late 60s by the RAND Corporation and involves collecting the estimates from a number of estimators, along with the reasoning behind their estimates. This information is then circulated anonymously to all of the estimators. The expert estimators can see how their colleagues came up with their estimations and determine if there were any assumptions or information that they had not considered in their estimations. Estimates are then revised and resubmitted. This process can be done for several rounds until the group has arrived at a consensus or has as least narrowed the range of estimates.

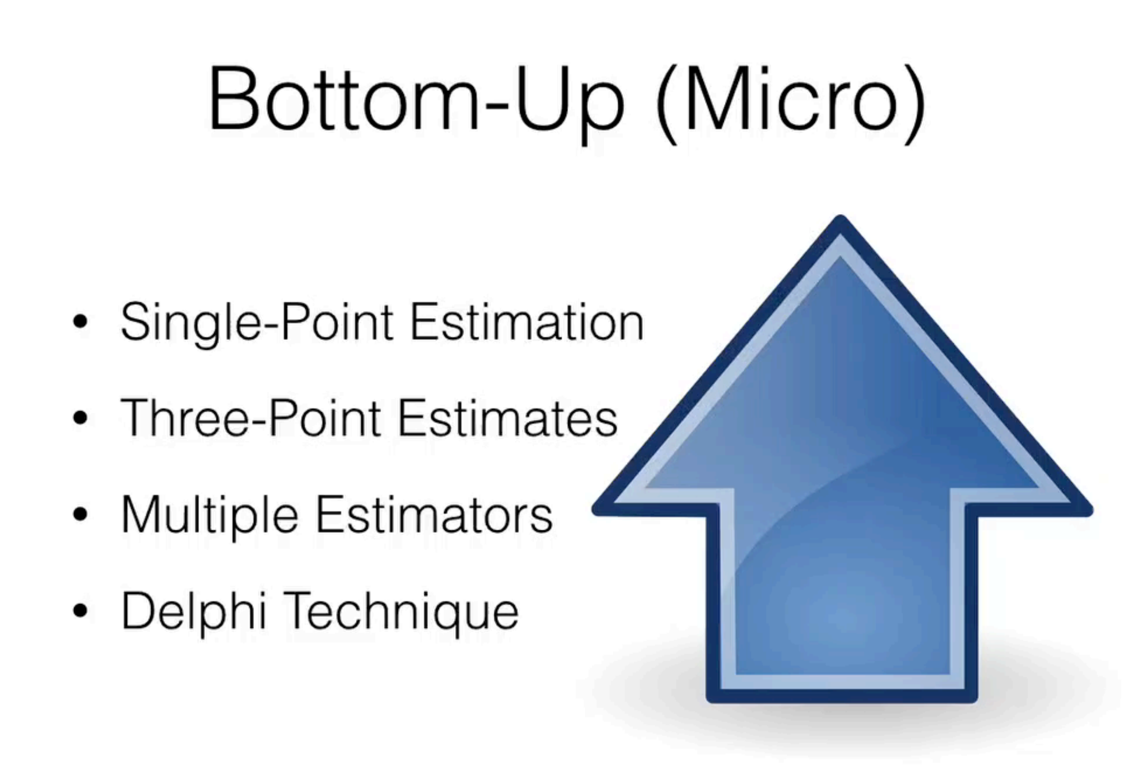
Table 7.4 Calculating T_e from three estimators

	Estimator 1			Estimator 2			Estimator 3			**AVERAGE**			
Act	(a)	(m)	(b)	(a)	(m)	(b)	(a)	(m)	(b)	**(a)**	**(m)**	**(b)**	**Te**
A	10	25	32	20	25	58	30	40	32	**20.00**	**30.00**	**40.67**	**30.11**
B	50	75	100	30	50	87	5	10	22	**28.33**	**45.00**	**69.67**	**46.33**
C	38	50	72	45	62	80	30	35	40	**37.67**	**49.00**	**64.00**	**49.61**
D	45	55	90	40	50	105	20	35	50	**35.00**	**46.67**	**81.67**	**50.56**
E	39	49	69	41	51	71	40	50	70	**40.00**	**50.00**	**70.00**	**51.67**
F	4	5	10	10	15	30	16	18	24	**10.00**	**12.67**	**21.33**	**13.67**
G	10	30	60	30	50	80	35	40	90	**25.00**	**40.00**	**76.67**	**43.61**

Bottom-Up Summary

Watch Video 7.3 for a summary of the bottom-up estimation techniques that were just covered.

Video 7.3 Summary of Bottom Up Estimation



You can also view this video at: http://pmf.video/video37

Section 2

PERT Analysis

Program Evaluation and Review Technique (PERT) was one of the first systems for diagramming and analyzing project networks. Many of the techniques covered in this and other project management textbooks originated with PERT. Over the years, the PERT concepts have been augmented and extended. As a result, many project managers don't directly mention PERT, but use a variation of the PERT system as it was developed in the 1950s.

One PERT technique that is particularly useful is the one for analyzing the variability in project time estimates. Estimate variability represents a substantial source of risk for any project. A PERT analysis can help project managers make better assumptions about the likely completion time for tasks and for the project. A PERT analysis gives the project manager the information needed to address estimate variability by adding time buffers and allocating contingency funds.

Three Point Estimates

A PERT analysis starts with a three point time estimate. For each activity, estimators provide:

- An optimistic time estimate (if all goes well, what is the shortest time period one could realistically expect for the completion of this activity?). This will be designated in calculations as **a**.
- The most likely time estimate (if all goes normally, what is the average time one would expect it would take for an activity to be completed?). This will be designated in calculations as **m**.
- A pessimistic time time estimate (if work goes poorly, what is the longest time period one could realistically expect for the completion of this activity). This will be designated in calculations as **b**.

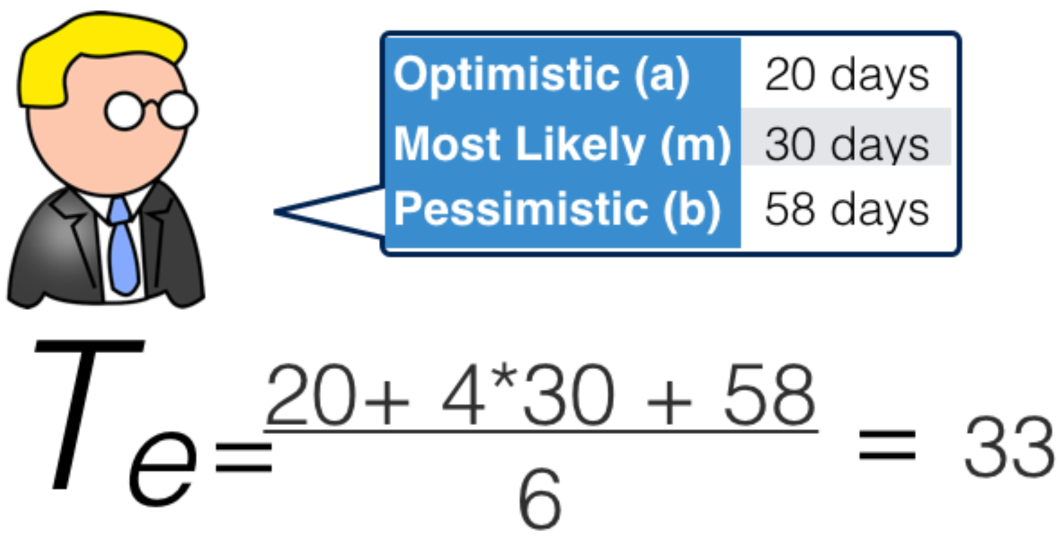
Figure 7.8 PERT analysis Inputs

Estimators provide us with optimistic (a) most likely (m) and pessimistic (b) estimates for activities.

PERT uses a weighted average to reflect the fact that the most likely estimate (*m*) should be weighted more heavily than the others. For PERT, this weighted average is called T_e, and is computed by the formula below. This can be adjusted by the project manager for different circumstances, but this is the generally accepted formula.

$$T_e = \frac{a + 4m + b}{6}$$

Figure 7.9 PERT calculation of expected activity duration.



This formula for calculating activity duration properly weights the most likely estimate.

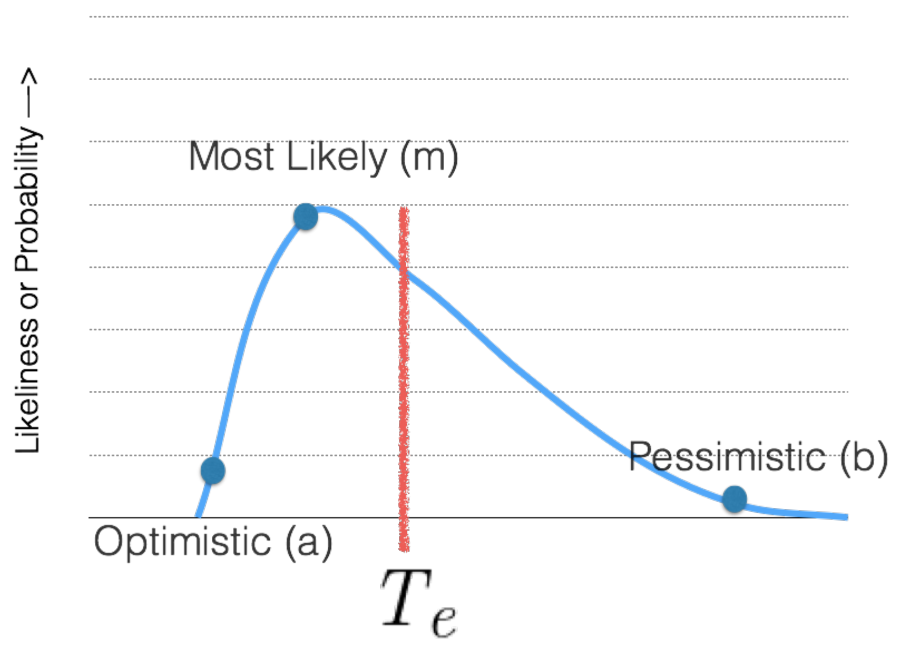
Project management studies have found that T_e values follow a beta distribution of probable completion dates. As a result, when given the values for a, m , and b for each task on the critical path, the project manager can calculate the probability of the project being completed within a given time period.

Standard Deviation and Variances

For calculations involving PERT, the calculation for standard deviation for project activities is as follows:

$$\sigma_{T_e} = \frac{a-b}{6}$$

Figure 7.10 Beta Distribution of Activity Completion.



For calculations involving PERT, the calculation of the variance for project activities is as follows:

$$\sigma^2 = \left(\frac{a-b}{6}\right)^2$$

Once the variance is calculated, the probability that an activity will complete within a given time period can be calculated. The standard deviations and variances for tasks on a given network path can also be summed and the probabilities for that entire path completing within a certain time period can be calculated.

More advanced simulations can use these variances to calculate probabilities of all network paths in order to produce a robust (although time consuming) model of a project's probable completion date, which paths/tasks present the most risk, etc.

The next section walks the reader through a simple PERT analysis to analyze the variability in a project and calculate the probability of a project getting done within the time defined by its critical path.

PERT Analysis Example

Table 7.5 presents the data for Project Omega. We have been given the activity, predecessor information, and three-point estimates for activity durations from which we have calculated T_e, standard deviation and variance. *Note: Expected time is rounded to the nearest whole number.*

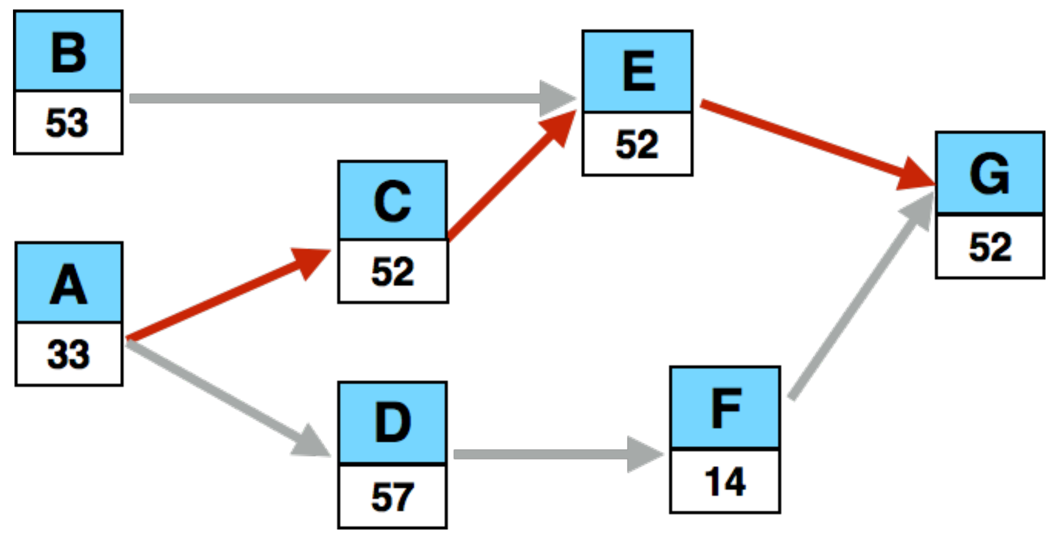
The next step is to look at which tasks are on the critical path. We can calculate this by hand or enter it into project management software. Either way that we do this, we find that the critical path is: Activity A ▷ Activity C ▷ Activity E ▷ Activity G.

Since all of the relationships are finish to start, it is easy to calculate the project duration by adding up the duration of all the critical path activities (See Figure 7.11 and Table 7.6). So the question a project manager would want to ask now is: **Given the variances of the critical path activities, what is the probability that Project Omega will finish in 189 days?**

Table 7.5 T_e, Deviation, and Variance for Project Omega

Activity	Pred.	Time estimates (a)	Time estimates (m)	Time estimates (b)	Expected time (T_e)	Stand Dev	Var
A	-	20	30	58	33	6.33	40.11
B	-	30	50	87	53	9.50	90.25
C	A	38	50	72	52	5.67	32.11
D	A	40	50	100	57	10.00	100.00
E	B,C	40	50	70	52	5.00	25.00
F	D	9	12	24	14	2.50	6.25
G	E,F	30	50	80	52	8.33	69.44

Figure 7.11 Network diagram for Project Omega.



Durations are based on T_e. Critical Path is highlighted in red.

Now we will go back to our list of project activities, but this time we want to just look at the critical path activities (see Table 7.6).

To determine the probability of completion, a formula is used that compares proposed schedule completion dates (T_s) with the time predicted by our critical path (T_e). This determines a statistical Z value and the probability of meeting the proposed completion date. The formula for this calculation is:

$$Z = \frac{T_s - T_e}{\sqrt{\sum \sigma_{T_e}^{\ 2}}}$$

This Z value can then be found in a probability table or calculated using a spreadsheet program like Excel.

Table 7.6 Deviation and Variance of Critical Path Activities

Activity	Pred.	Time estimates (a)	(m)	(b)	Expected time (T_e)	Stand Dev	Var
A	-	20	30	58	33	6.33	40.11
C	A	38	50	72	52	5.67	32.11
E	B,C	40	50	70	52	5.00	25.00
G	E,F	30	50	80	52	8.33	69.44
				SUM	**189**	**25.33**	**166.67**

Probability of Completion

In Table 7.7, we have entered the proposed completion date of 189 days (the same as our predicted duration) into a spreadsheet that will compute the probability of completion for any proposed time period. Starting with our critical path time (189 days), Project Omega has only a fifty percent chance of completing in 189 days or less (what we would expect given the distribution curve in Figure 7.10). We can use this same spreadsheet to look at various completion dates, and assess the probability of completion give those dates (see Table 7.7). Once we arrive at a probability that

Table 7.7 Probability of meeting critical path date.

Activity	Pred.	Time estimates (a)	(m)	(b)	Expected time (T_e)	Stand Dev	Var
A	-	20	30	58	33	6.33	40.11
C	A	38	50	72	52	5.67	32.11
E	B,C	40	50	70	52	5.00	25.00
G	E,F	30	50	80	52	8.33	69.44
				SUM	**189**	**25.33**	**166.67**
				Proposed Completion Time	**189**		
				Probability of Completion (%)	**50.00%**		

There is only a 50 percent chance that our project will complete by 189 days.

we feel comfortable with, we can then look to add buffer times and contingency funds to deal with this scheduling risk.

Please note that this is a very basic explanation of PERT, with a simple example. However, this should provide a good foundation for understanding the wide variety of analysis that can be conducted using time estimates and how project managers assess the risk that time estimates present in their projects.

Table 7.8 Probability of meeting proposed completion dates.

Activity	Pred.	Time estimates (a)	(m)	(b)	Expected time (T_e)	Stand Dev	Var
A	-	20	30	58	33	6.33	40.11
C	A	38	50	72	52	5.67	32.11
E	B,C	40	50	70	52	5.00	25.00
G	E,F	30	50	80	52	8.33	69.44
				SUM	**189**	**25.33**	**166.67**
	Proposed Completion Time				**189**		
	Probability of Completion (%)				**50.00%**		
	Proposed Completion Time				**200**		
	Probability of Completion (%)				**80.29%**		
	Proposed Completion Time				**211**		
	Probability of Completion (%)				**95.58%**		

PERT Summary

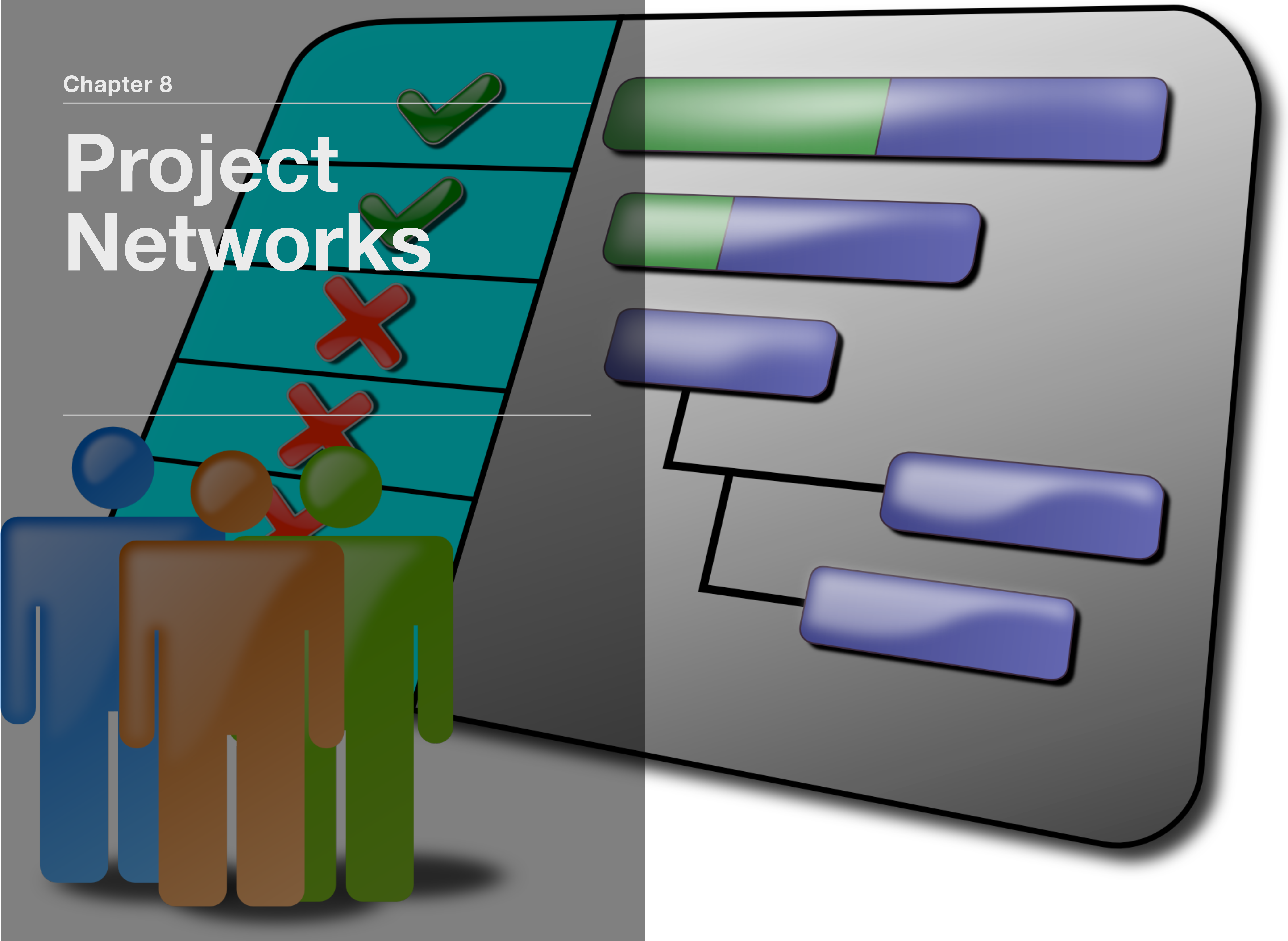
1. A PERT Analysis assesses the risk associated with time estimates
2. Time buffers and contingency funds can be added to the project to mitigate this risk.
3. A PERT analysis starts with three point estimates, which provide an optimistic (a), most likely (m), and pessimistic (b) estimate of activity duration.
4. The estimated time (T_s) is normally calculated as:

$$T_e = \frac{a + 4m + b}{6}$$

5. To complete a simple PERT analysis:
   1. Calculate T_s duration values for each task.
   2. Determine critical path.
   3. Determine variances for critical path activities.
   4. Estimate probabilities that the project will complete within a given time period.

Chapter 8

Project Networks



Chapter 8 Overview

The network diagram provides a visualization of how a project's activities fit together. This can be used to identify the risks and opportunities that are inherent in a project schedule. The two sections in this chapter explain how to create networks diagrams that properly sequence and order project activities according to dependencies and resource constraints. The creation of a network diagram determines the critical path. This process also identifies those tasks that can be delayed without delaying the entire project. Network diagrams are also used to analyze the project schedule to find opportunities to compress the schedule and smooth resource usage (See Chapter 9).

The first section in this chapter introduces methods for creating network diagrams, explains how to create activity on node (AON) diagrams using finish-to-start relationships, and explains how to calculate these values for each task:

- Early Start
- Late Start
- Critical Path
- Early Finish
- Late Finish
- Slack

The second section in this chapters shows how changing the relationships between tasks from simple finish-to-start relationships to start-to-start, finish-to-finish, and start-to-finish relationships changes network calculations.

The thir

Learning Objectives:

- Understand how Activity on Arrow and Activity on Node diagrams represent a project network.
- Understand the concept of the critical path and how to determine the critical path of a network.
- Understand how to complete a forward and backward pass through a network.
- Explain what ES, EF, LS, LF, and Slack mean.
- Understand the four types of relationships between activities: Finish to Start, Start to Start, Finish to Finish, Start to Finish.
- Be able to complete a forward and backward pass through a network using all four types of relationships.
- Understand the difference between free and total slack.
- Define positive and negative slack.

Section 1

Create the Project Network Diagram

The network diagram visualizes how a project’s activities are sequenced and is useful in uncovering risks and opportunities that are inherent in a project’s schedule. The activities in the network diagram are derived from the work packages of the Work Breakdown Structure (WBS). The time durations of tasks have been calculated by one or more of the bottom-up time estimation techniques presented in previous chapters. All of the WBS activities must be accounted for in the network either by summarizing the activities for a deliverable or by individual activities.

Once a list of activities is constructed, and vetted by subject-matter experts, and the mandatory and discretionary dependencies worked out, these activities can be sequenced in a network diagram. There are two main methods for creating network diagrams: the Arrow Diagramming Method and the Precedence Diagram Method.

Arrow Diagramming Method (also known as Activity on Arrow)

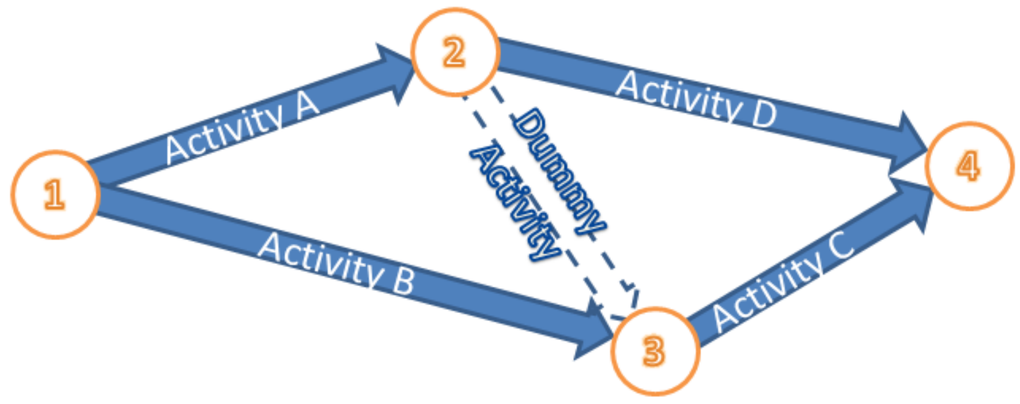
The Arrow Diagramming Method (ADM) is a technique that uses arrows to represent activities (see the figure to the right). "Nodes" or circles represent an activity's start and stop time, and also indicate the relationship between activities. As a result, this method is also known as the activity-on-arrow (AOA) method.

In the Arrow Diagramming Method, the length of the arrow proportionally represents the duration of the activity. A major drawback to ADM is that it only shows finish-to-start relationships (a task must complete before the next task can begin, which is often not the case in complex projects). In ADM, a so-called dummy task is sometimes used to indicate precedence (the order in which activities are completed) when it can't easily be expressed using other methods. These dummy tasks have a completion time of 0.

With this method, the node on which an activity begins is called a I-node, and the node on which an activity ends is called an J-node.

The use of ADM continues to decline, largely due to the limitations described above and because modern project management informations systems (MSproject, ProjectLibre, Fasttrack, etc.) normally create network diagrams using the precedence diagram method.

Figure 8.1 Arrow Diagramming Method

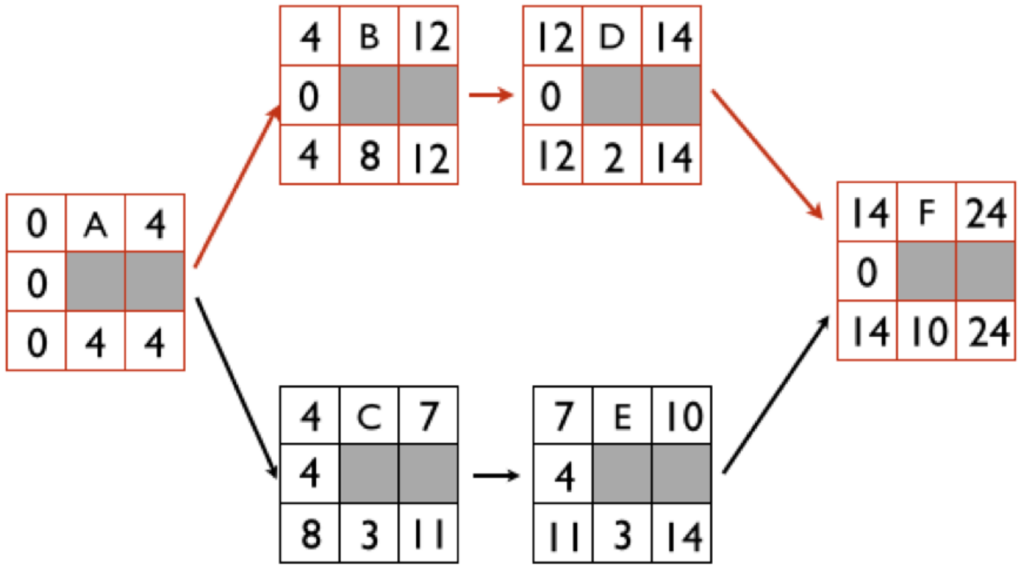


Precedence Diagram Method (also known as Activity on Node)

The precedence diagram method uses boxes (called nodes), to represent activities, and arrows to show dependencies (see the figure below). Once the network is diagrammed, a number of important pieces of information can be calculated:

- Critical path
- Slack time for non-critical activities.
- Early and late start times
- Early and late finish times

Figure 8.2 Precedence Diagram Method

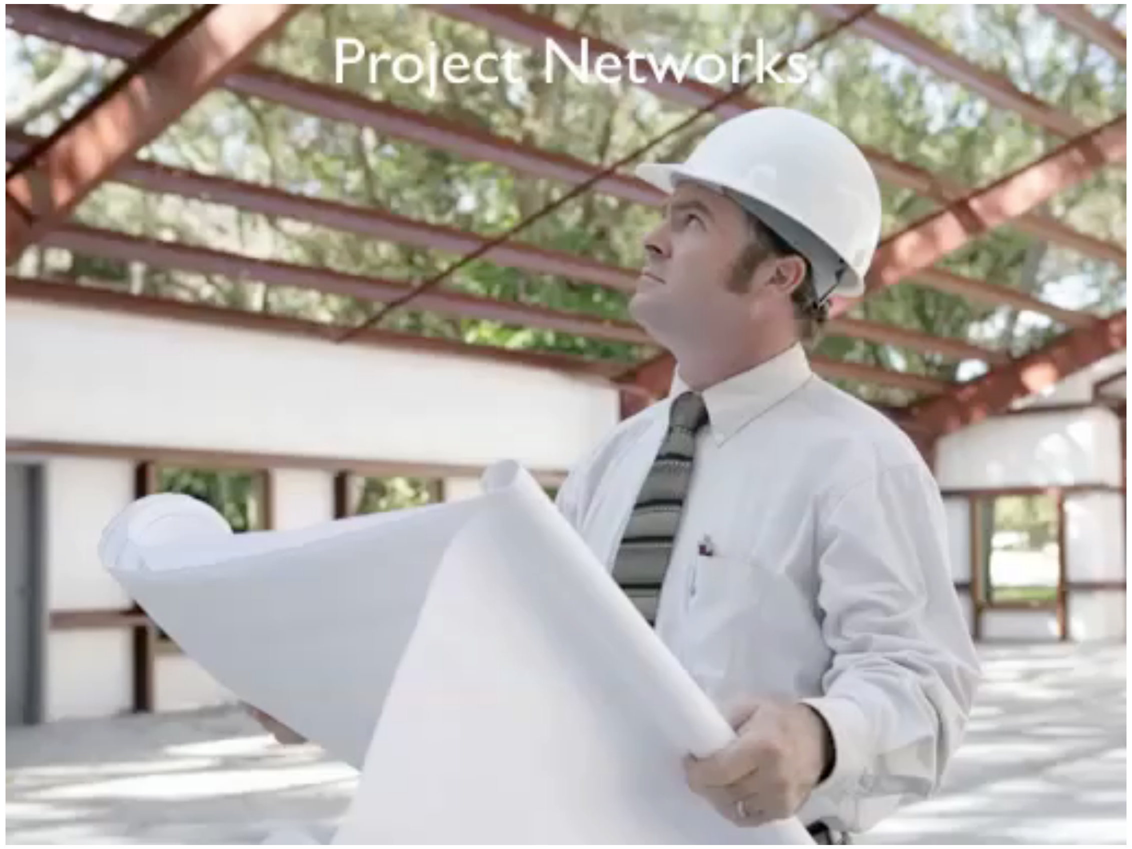


In this example, each activity is represented by a letter, and the numbers represent various properties of the activity.

Network Diagrams and the Critical Path

Watch the video on project networks to learn more about how network diagrams are created and how the critical path of a project is determined.

Video 8.1 Project Networks



You can also view this video at: http://pmf.video/video5

Forward and Backward Pass

Once a network diagram has been made and estimated activity durations have been assigned to each activity, the following attributes of each activity can be calculated:

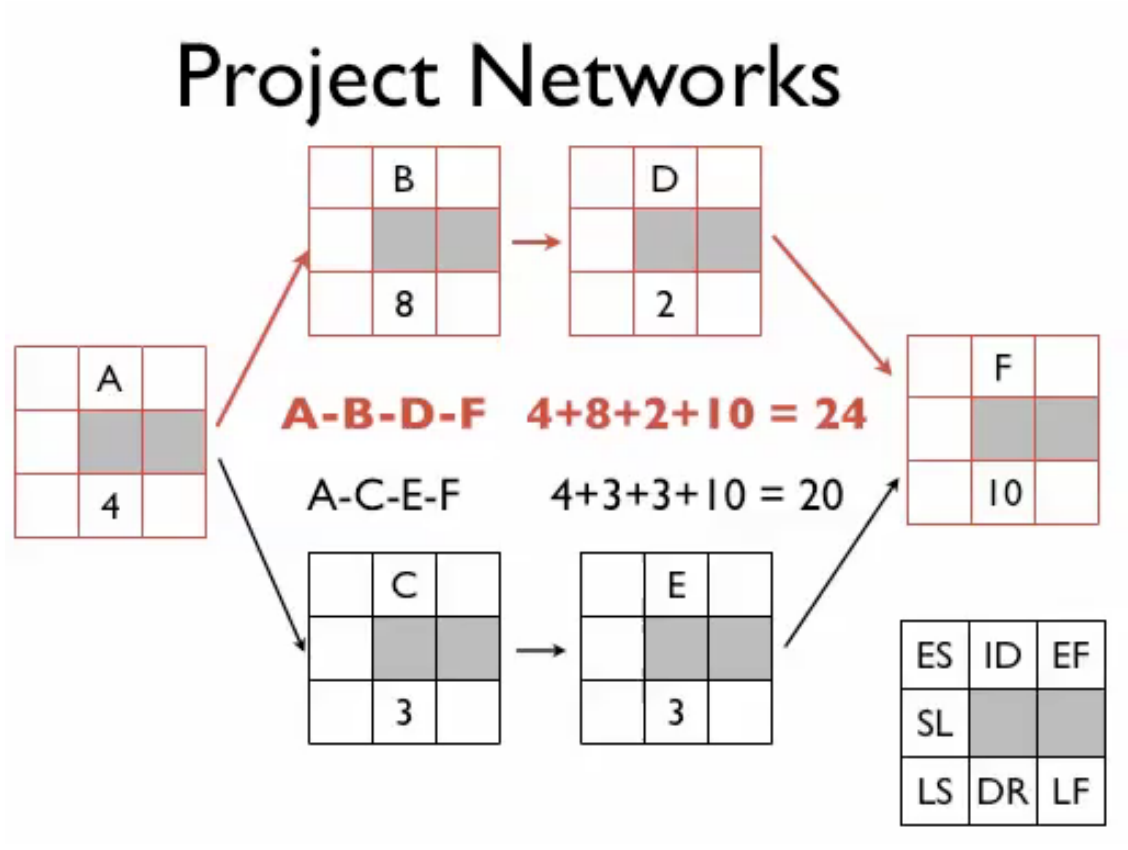
- Early start time (ES)
- Late start time (LS)
- Early finish time (EF)
- Late finish time (LF)
- Slack or float (SL or FL)

These activity attributes are calculated using two processes: the forward pass and the backward pass. Watch Video 8.2 to learn how to make these calculations.

The forward and backward pass are also used to fully calculate the critical path(s) in a project.

Note: there can be instances where the start of an activity is on the critical path, but the finish is not on the critical path. This is unusual, but can happen depending on the types of relationships that are involved (see section 2 of this chapter: Advanced Network Diagrams).

Video 8.2 The forward and backward pass



You can also view this video at: http://pmf.video/video6

Section 2

Advanced Network Diagrams

Network Diagram can be extremely complex. This section will explore some of the other relationships tasks can have to each other and how that can alter the calculations for the forward and backward pass.

Task Relationships and Lags

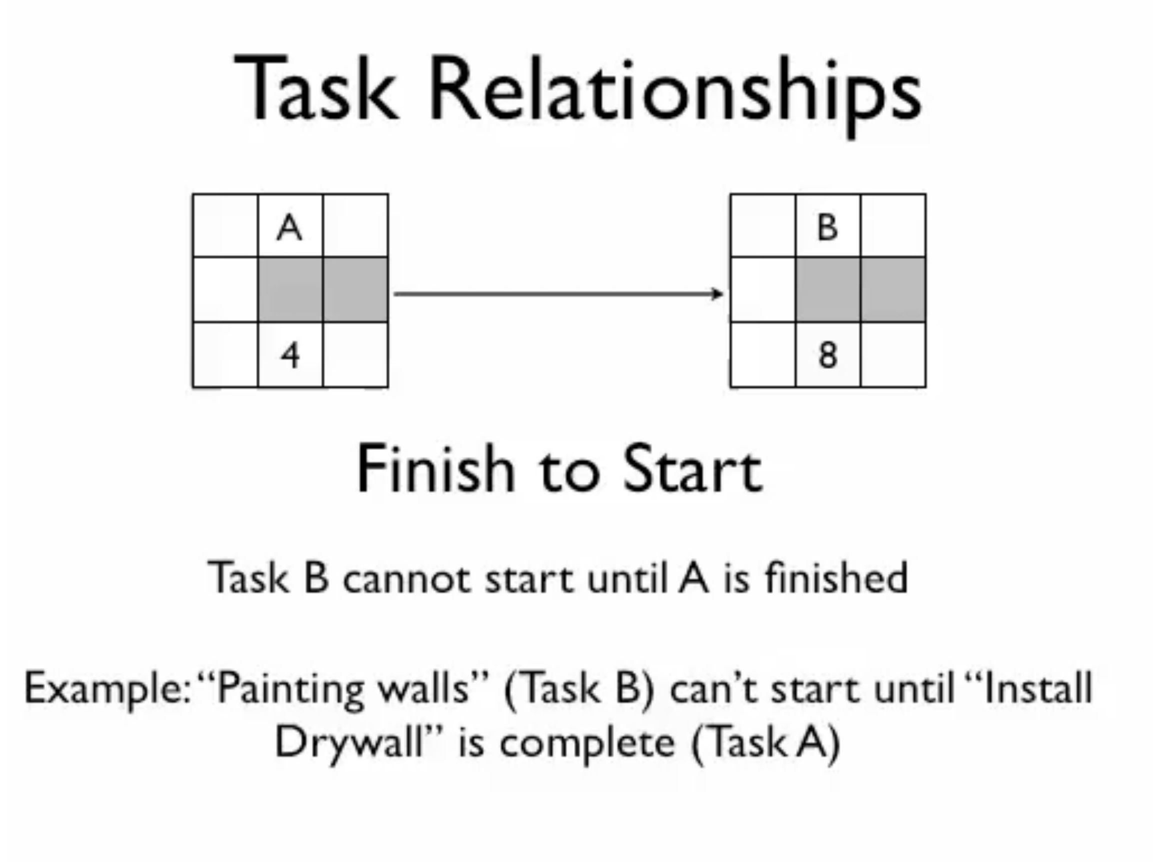
In the previous section, just one type of dependency was used between tasks in the network: Finish to Start. However, there are four different types of dependency that can be used to link tasks.

- Finish to Start
- Start to Start
- Finish to Finish
- Start to Finish

In addition, there can be lags (delays) introduced in these dependencies. For example, if a task involves ordering materials and then using those materials to make something else, the time it takes to ship the product would need to be accounted for in the schedule. Another common example is when there are delays due to the need for paint to dry, concrete to cure, etc.

Lags don't use up resources and don't add any direct costs to a project. However, they do take time, and therefore must be built into our network. Watch Video 8.3 to learn how these four types of relationships are used and how project managers account for lag times in a project network.

Video 8.3 Task Relationships and Lags



You can also view this video at: http://pmf.video/video7

Activity Float or Slack

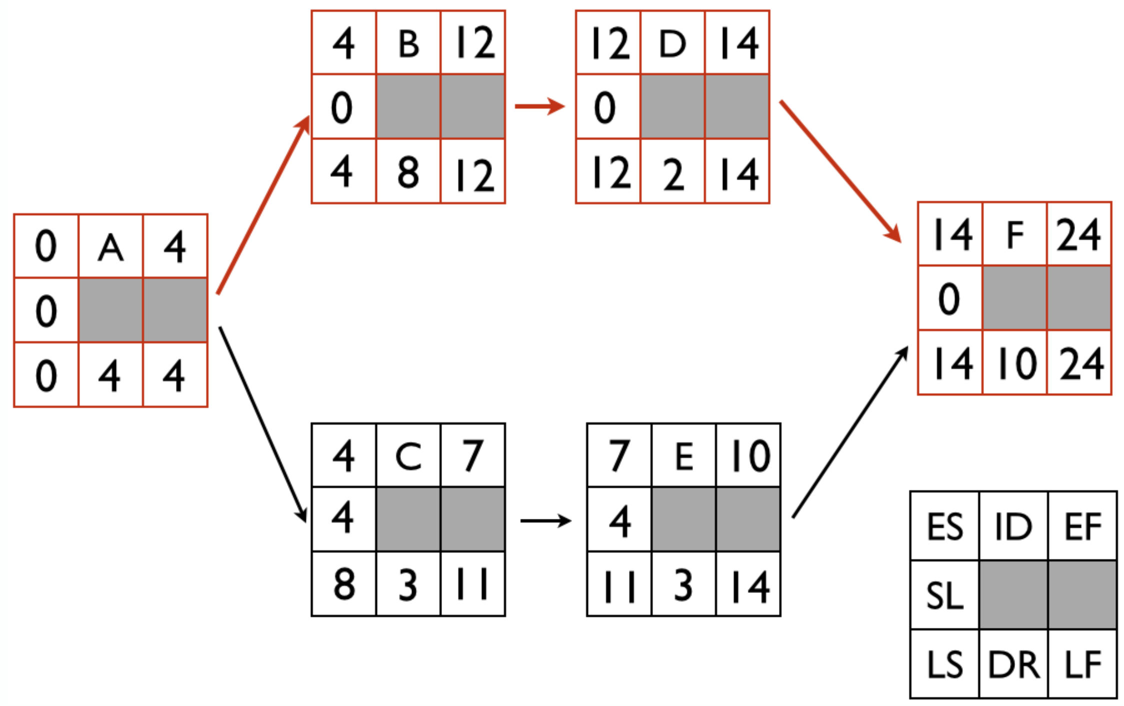
By definition, slack (or float) “is the amount of time that a task in a project network can be delayed without causing a delay to the project” (from Wikipedia).

Consider the diagram in Figure 8.3. Notice that the critical path (A-B-D-F) has no slack and a total time of 24 days. The other path (A-C-E-F) has a total duration of 20 days. Task C and Task E each have 4 days of slack.

Free slack is the amount of time that a task in a project network can be delayed without causing a delay to subsequent tasks. In Figure 8.3, Task C has 0 days of free slack (since any delay in its finish will delay the start of Task E), and Task E has 4 days of free slack (since Task F will be waiting for D to finish for 4 days before F can start). In the example in Figure 8.3, both Task C and Task E have 4 days of free slack. Does that mean that Task C can be delayed 4 days AND Task E can be delayed 4 days without delaying the project? No. If Task C is delayed 4 days and the forward and backward pass is re-calculated, Task E will now have no slack and every task in the network will now be on the critical path.

While the forward and backward pass calculation show that C and E have 4 days of slack, C and Task E share that four days of slack. Between them they have a total of 4 days of slack. **Total slack** is the amount of time that a path in a project network can be delayed without causing a delay to the project completion date. The C-E path in this network can be delayed by a total of 4 days without affecting the project end time.

Figure 8.3 Total vs. Free Slack



This may all seem obvious in simple network diagrams, but it is an important distinction as our network diagrams get more and more complex.

Positive and Negative Slack

You might also hear the terms Positive Slack and Negative Slack. These terms are generally used when referring to the overall duration of a project, as indicated by the network schedule, and comparing that to the desired completion date for the project. A project that is not on track to meet the desired completion date, would have negative slack (meaning that the project team would need to get tasks finished in less time than scheduled to meet the deadline; for information on how to do this, see the Chapter on Schedule Compression).

On the other hand, if a project is ahead of schedule, people might say that the project has positive slack. That is, all of the tasks can experience some delay and the project will still meet our desired completion date. If this happens, it it a sign that the project manager should evaluate the resource allocations to see if some of that positive slack can be used to reduce project costs.

Milestones

Milestone are used to mark a special goal or stage of our project. They don't take any time or consume any resources, but maybe noted with a node on the project network.

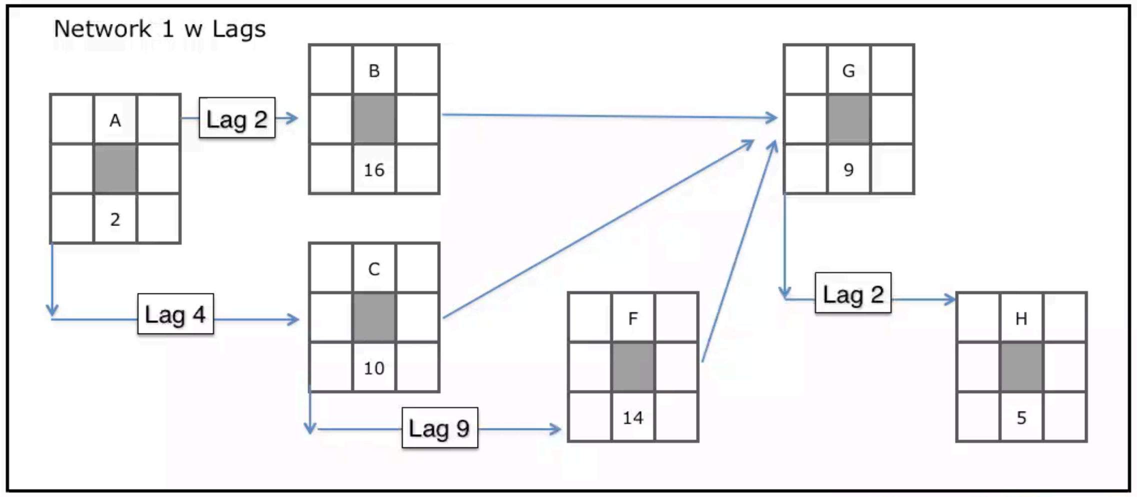
For information on how to create and use milestones in MS Project, watch this video Creating and Using MileStones in MS Project: http://pmf.video/video34

Forward and Backward Pass Revisited

As you can imagine, a network diagram with several different types of relationships and lags can get very tricky to understand. It can be difficult to perform the forward and backward pass correctly on such networks. One method that can help is to consider the start and finish of an activity to be independently of each other. That is, the finish of a relationship can have relationships with other tasks that "overrides" the relationship it has with the start of the task.

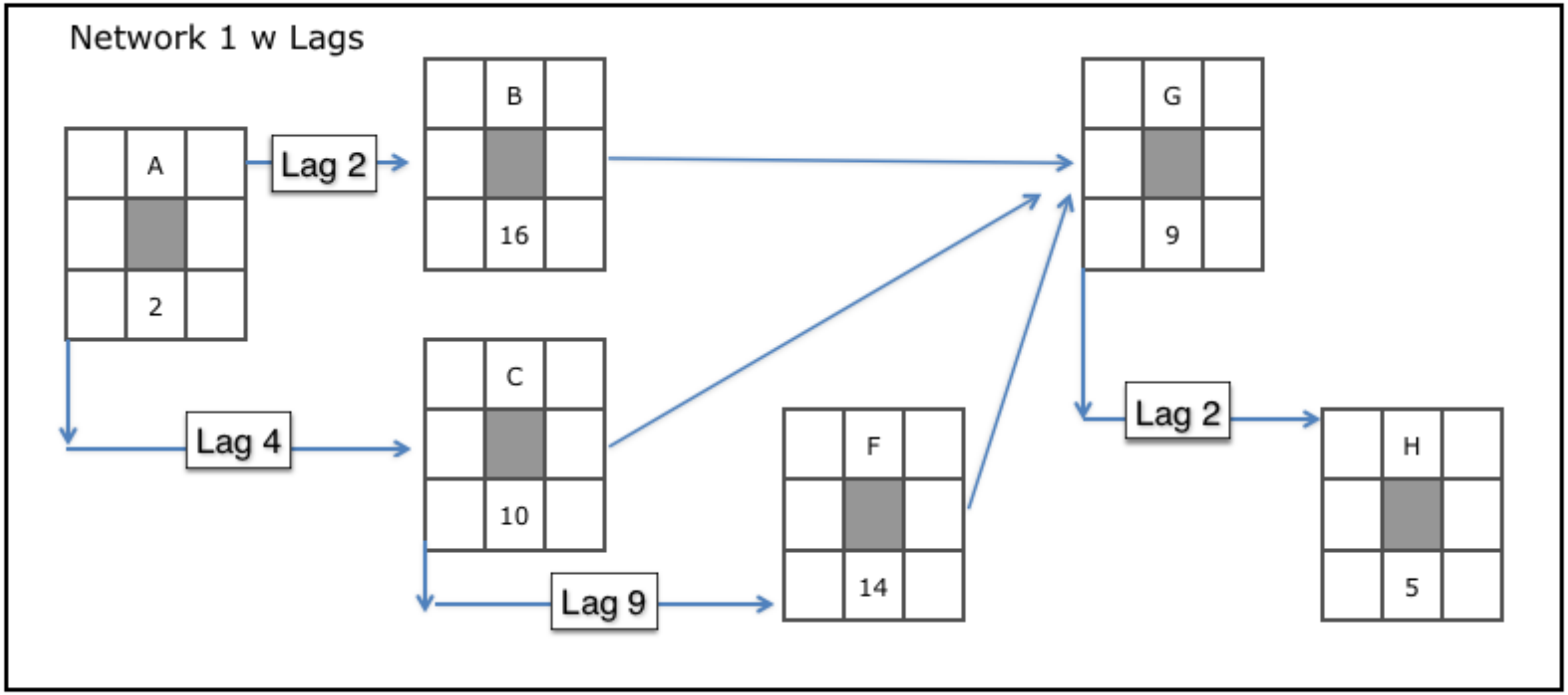
Watch the Video 8.4 (Network 1 w Lags) to see how the forward and backward pass are calculated for the network shown in Figure 8.4.

Video 8.4 Network 1 w Lags



You can also view this video at: http://pmf.video/video8

Figure 8.4 Complete the forward and backward pass on the network while watching Video 8.4



Chapter 9

Reducing Project Duration

Chapter 9 Overview

There are several reasons that a project manager might need to reduce the amount of time that a project takes. The first and foremost reason is that the project needs to be done in less time than the current network schedule will allow. There might also be incentives for finishing the project early (or penalties for finishing late). A project manager whose project has experienced delays can use the techniques described in this chapter to get the project back on schedule.

The one and only section in this chapter provides an overview of the ways to reduce project time and then describes in detail:

- Fast-tracking
- Laddering
- Crashing

Learning Objectives:

- Understand the options available to project managers who need to reduce project duration.
- Understand how to fast-track a project.
- Describe the advantages and disadvantages of fast-tracking.
- Understand the concept of laddering
- Understand crashing and how to calculate the optimum time point for a project.

Section 1

Schedule Compression

This section covers the common schedule compression techniques used by project managers, when they should be used, and the trade-offs between different methods.

Compressing the Schedule

There are several ways to reduce the amount of time a project takes without outsourcing, reducing scope/quality, increasing overtime, or generating rework. Three common techniques can be used to compress the network project schedule: Fast Tracking, Laddering, and Crashing.

Keep in mind that all project compression techniques involve trade-offs and usually increase the risk of something going wrong with the project. The decision to reduce the project completion time should be considered carefully. For a good discussion of the trade-offs and pitfalls of schedule compression, see Crashing in Project Management: A Comprehensive Guide by Donald Patti: http://pmf.video/link3

Fast-Tracking

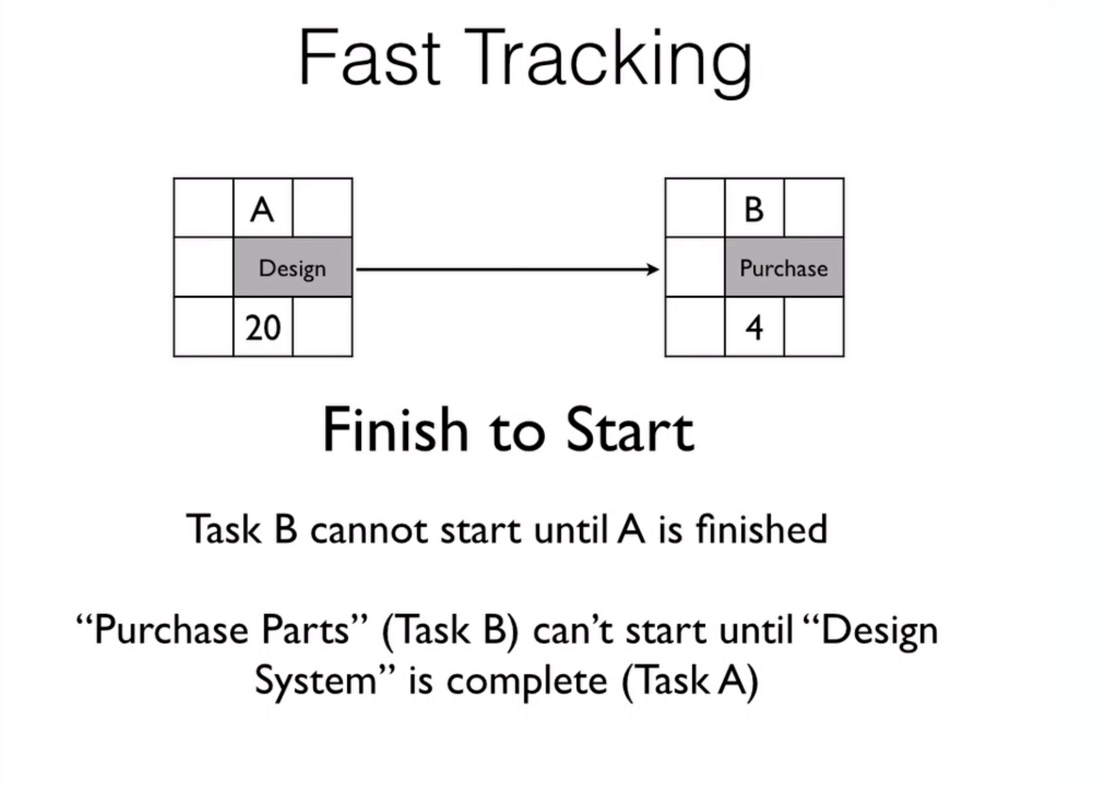
Fast-tracking is a way to compress a project schedule without increasing direct costs. Watch Video 9.2 for a brief introduction to the concept of fast tracking.

While the video shows the use of start-to-start relationship to complete tasks in parallel, finish to finish relationships can also be used. Either will cause activities to be performed in parallel.

Fast-tracking is used:

- Before a project is started. Good project managers will explore all the possibilities for the project network schedule. However, they need to use their expert judgement to balance the benefits of fast tracking with the risks (risks include increased cost and increased length of the project).
- When a project is falling behind and it needs to get back on schedule..

Video 9.2 Fast Tracking



You can also view this video at: http://pmf.video/video9

How much can a project be fast tracked?

Each industry and type of task will have its own guidelines, but usually activities can be fast-tracked by up to 33%. In other words, the second activity can begin after the first activity is 66% complete. This is a good balance between the benefits of a faster schedule and the increased risk of rework and problems arising from a more complex project network.

How does fast tracking increase risk?

First of all, a project that is fast tracked is more complex. There are more people working on the project at the same time, which means that the project manager and work supervisors have more to monitor and manage. There is also the possibility that work done simultaneously will result in re-work.

Here is a great example of this concept from Joel Kohler from his paper "Fast Tracking or Back Tracking?"

> *Let's look at a practical example: a home improvement project planned for completion in 10 days. If we fast track the project and simultaneously paint the walls while laying the carpet, it looks like we could finish in five days.*
>
> *So what's the risk? By simultaneously painting and laying carpet, there's a risk of getting paint on the carpet. Back tracking to clean paint from the carpet lengthens the schedule again. This mess and delay would not have occurred if the painting finished before carpet laying began.*

Other ways that fast tracking can increase risk:

- When there is less time for inspection and customer approval defects may not be detected until later in the project (when they are more expensive to fix).
- Project Manager has more to keep track of and the potential for an error to occur is increased.
- It is more difficult to make changes to the project. For example, if a project fast-tracks construction on a new building before the design is finalized, it will be very difficult (and expensive) to modify the design in major ways.

What is the PMI Definition of Fast Tracking?

Fast tracking: A schedule compression technique in which activities or phases normally done in sequence are performed in parallel for at least a portion of their duration.

-Section 6.6.2.7 , page 181 from the Fifth Edition of the PMBOK Guide.

How much does fast tracking cost?

In theory, there should be no increase in direct project costs. But if the risks mentioned above do occur, then the costs could be great. All stakeholders need to be made aware if the project manager is using fast tracking, there are risks associated with this technique.

The reader should not infer from this discussion that fast tracking is a poor idea; they should be aware that it is not a panacea or magic bullet for compressing a schedule. Every modification to a project has trade-offs and project managers need to be honest with themselves and the stakeholders about those trade-offs.

Laddering

Another approach related to fast tracking is the concept of laddering. This is primarily used in situations where a lot of the project activities repeat, as in road construction, or building a series of houses in a development, etc. As a result, many project managers will not use or encounter this concept. Watch the video on laddering for a quick introduction to this topic.

For more information on laddering, start with: "An Investigation on the Impact of Laddering Technique in Project plan: a Case of Road Construction" by Seyed Ali Hosseini, Taravatsadat Nehzati, Mohammad Amin Okhowat, and Norzima Zulkifli: http://pmf.video/link4

Video 9.3 Laddering

You can also view this video at: http://pmf.video/video10

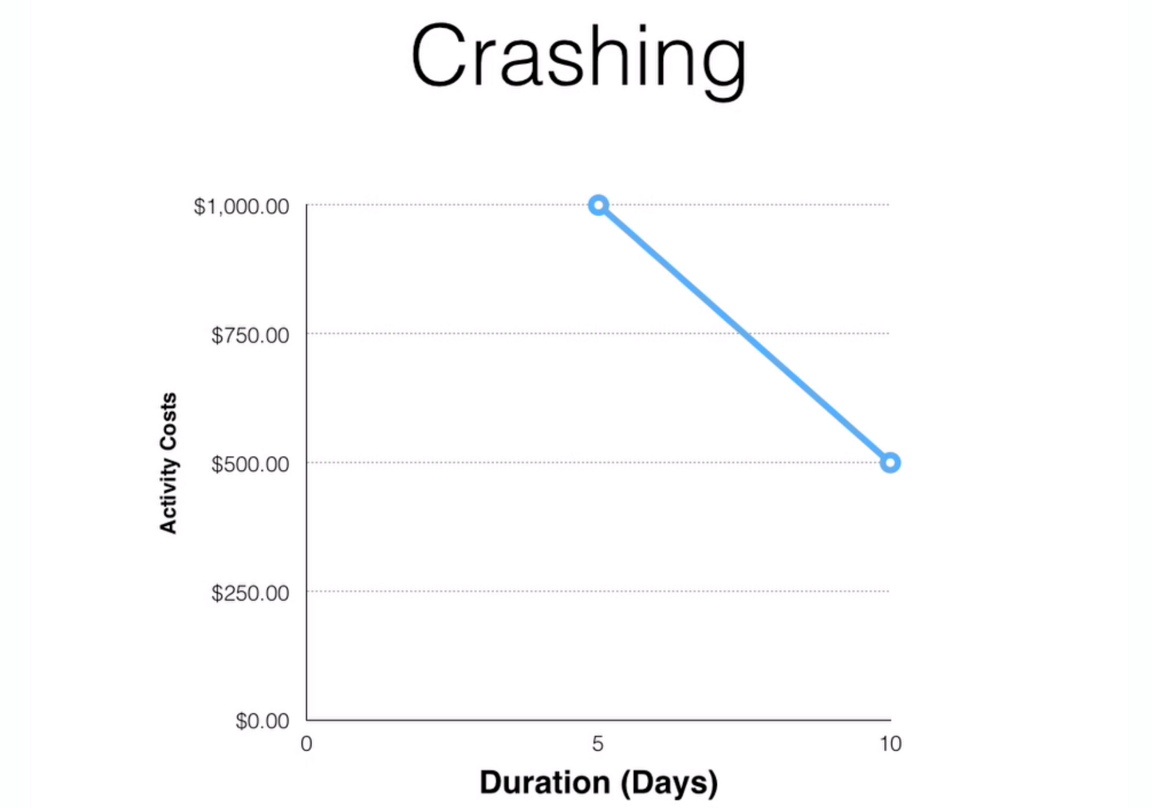
Crashing a Project

By adding resources to a project, it maybe possible to reduce the amount of time that our project takes. This might be done to deal with negative float, but it might also be done to address cost control or increase profits. Watch Video 9.4 for a brief discussion and an introductory project crashing exercise.

Crashing Summary

- Crashing always involves adding resources, so the direct costs of the project will increase when a project is crashed.
- Crashing may lead to overall savings for the project if there are incentives for getting the project done on time (or avoiding penalties). Savings can also be realized by a reduction in the total indirect costs (which accumulate with time).
- In order to crash a project, the project managers evaluated which critical path task(s) can be crashed for the least amount of money. Depending on the complexity of the network, multiple tasks may have to be crashed in order to reduce the project time.
- Crashing can be used to get a project "back on track" or can be used when planning to calculate the optimum schedule for the project.
- Resource availability and staffing will have to be accounted for in a crashed schedule.

Video 9.4 Crashing a Project



You can also view this video at: http://pmf.video/video11

Additional Methods to Reduce Project Time

There are several additional ways that to analyze a project schedule in order to reduce the time required to complete a project. Options include:

- **Outsource various tasks**. Is it better to complete the work using internal resources or to get experts from outside the organization? It maybe possible to hire an outside contractor who has more experience or who specializes in this type of task. While outsourcing might increase costs, and the project manager might lose some direct supervision of the project/staff, it can often be a much faster approach.
- **Reduce scope.** The amount of work required to complete the project can be reduced by decreasing scope. This might save both time and costs (resources), but it is likely to also reduce customer satisfaction with the project.
- **Reduce quality.** This can save cost, resources, and time, but could also increase the risk of failure or re-work. Reducing quality can also reduce customer satisfaction.
- **Increase overtime.** By increasing the time that people work, it might be possible to complete key tasks on the critical path early. This can increase costs for employees who are paid overtime. And if the salaried employees are overworked for long periods, there is a risk of decreasing morale and reduced overall productivity.
- **Have the owner take more responsibility.** If the project is being completed for an outside organization, it might be possible to shift some of the work to them, freeing up internal resources to "double up" on other tasks.
- **Do it Twice: Fast and Then Correctly.** If something must be in place by a particular deadline (ribbon cutting with a dignitary, etc.) it might be possible to complete the minimum required to quickly reach a point where the product or service is useful. Then later the task can be fully completed. This is probably the worst option as it increases cost and time in the long run.

Reducing Project Duration Summary

- Fast-tracking involves changing task relationships so more tasks can be completed in parallel.
- Fast-tracking and laddering don't increase project costs but can increase risk.
- Crashing always increases the direct costs, but a decrease in indirect costs or incentive funds can make crashing profitable.

Chapter 10

Earned Value Analysis

Chapter 10 Overview

Earned Value Analysis (EVA) is one of the best tools for summarizing a large project's progress and forecasting its final cost. Earned value analysis is not required for all projects, and is not appropriate for all projects, but it is an important tool that project managers can draw on when needed.

The first section in this chapter explains the basic inputs and concepts of earned value. The following inputs are explained:

- Planned Value (PV)
- Actual Costs (AC)
- Earned Value (EV)
- Budgeted At Completion (BAC)

This section also explains various ways to estimate project progress.

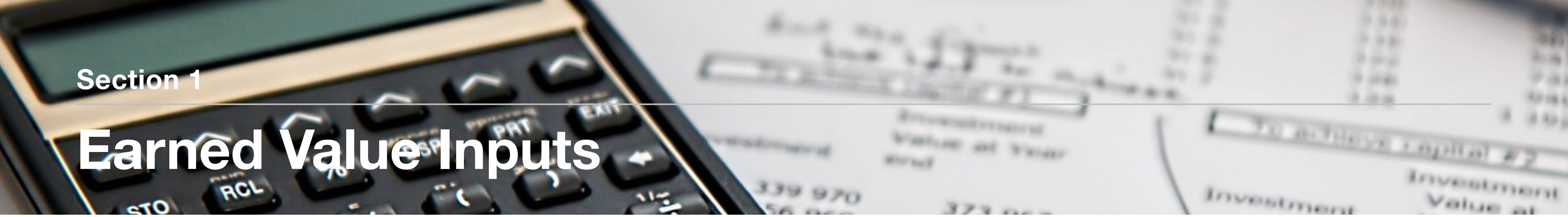
The second section concentrates on how to make make earned value calculations using the inputs mentioned above, how to interpret earn value results, how to forecast where a project is headed, and what performance will be required in the future to make sure the project is finished within budget.

The following earned value measures are covered:

- Cost Variance (CV)
- Schedule Variance (SV)
- Cost Performance Index (CPI)
- Schedule Performance Index (SPI)
- Percent Complete Index-Budget (PCIB)
- Percent Complete Index-Cost (PCIC)
- Estimate to Complete (ETC)
- Estimate cost At Completion (EAC)
- Variance At Completion (VAC)

Learning Objectives:

- Understand the inputs required for an earned value analysis.
- Understand a time-phased budget.
- Understand how to calculate and interpret the various earned value analysis metrics.



Section 1

Earned Value Inputs

Earned value analysis (EVA) is a monitoring and controlling process that compares project progress to the project baseline (original plan). EVA measures the performance of a project in terms of cost and schedule. It can tell the project team if a project is:

- Behind Schedule
- Ahead of Schedule
- Under Budget
- Over Budget

EVA provides hard numbers for making these judgements and can be used to forecast where a project will end up in terms of time and cost. As a result, EVA helps the project manager clearly communicate project progress to all stakeholders, and can focus the attention of the project team on any changes needed for the project to be completed on time and on budget.

Most project management information systems (PMIS), can calculate earned value metrics if a baseline is properly set and the earned value inputs are provided.

Project managers who do not conduct an earned value analysis run the risk of misinterpreting or miscommunicating the meaning of the project information that is collected during the execution phase.

For example, assume that the direct costs of a project are budgeted at $100,000, and the project is scheduled to take 12 months. If it is three months into the project and $25,000 has been spent, a naive project manager might assume that the project is 25% done and is on track to finish within the project timeline and budget.

In this example, the project is certainly 25% done as far as the time allowed for the project, and 25% done with the budget, but what is not known is which activities have been worked on and if those activities are complete or still in progress. If only 10% of the scheduled work has actually been completed, then the project may be in trouble. Alternatively if 50% of the scheduled work has been completed, then the project may end up being done much earlier and with much less expense than planned. Either situation requires action:

- If a project is going to be over-budget and/or take more time, the project manager needs to figure out if what can be done to correct the situation. Should they try to get more resources and time, or should they re-evaluate the project entirely (see section on Sunk Costs).
- If a project is going to be done in significantly less time and/or with significantly less cost, then the project manager should see if some of the resources allocated for the project can be released to other projects and priorities in the organization, and the impact of an earlier completion date should be evaluated.

Before attempting the calculations involved in an earned value analysis of a project, it is important to understand the three basic inputs for EVA calculations. The three basic inputs are Planned Value (PV), Actual Costs (AC), and Earned Value (EV).

Planned Value (PV)

Planned Value—also known as Budgeted Cost of the Work Scheduled (BCWS)—reflects the amount of money that the project is expected to spend on project activities. For each activity there is a total Planned Value (cost). More importantly, the amount that was going to be spent on each activity over time is also know.

> *PV is "the authorized budget planned for the work to be accomplished for an activity or work breakdown structure component, not including management reserve. This budget is allocated by phase over the life of the project, but at a given moment, planned value defines the physical work that should have been accomplished" by this time.*
>
> *—PMI PMBOK*

Consider the information presented on Project Tweet in Table 10.1. The amount that the project team thinks an activity will cost is called the planned value for that activity.

Table 10.1 Project Tweet

ID	Task	Activity Budget (PV)
1	Design prototype board	$468
2	Order sensors	$156
3	BreadBoard sensors and connections	$546
4	Outline programming requirements	$390
5	Draft preliminary program	$1,092
6	Load program and test	$156
7	Set up "real" twitter account	$39
8	Develop final test criteria	$78
9	Test	$780
10	Put into case	$39
11	Complete perm install	$156
12	Write up details and post	$234
	Total	**$4,134**

Budgeted At Completion (BAC)

The sum of the planned value for all of the activities is also known as Budgeted At Completion (BAC) and is what should be budgeted for the cost of the project activities. This is referred to as the direct costs of the project; contingencies, indirect costs, management reserves, etc., are not included in this total. In the example in Table 10.1, the BAC is $4,134.00.

Time-Phased Budget

PV become much more valuable as part of a time-phased budget: a table that shows PV values for each task during a given week or day. Table 10.2 show the time-phased budget for Project Tweet.

For example, by looking at Table 10.2 it is possible to know the following about what the status of Project Tweet should be the end of week one.

- While the total PV of Activity 1 (Design prototype board) is $468, only $78 was planned to be spent on this activity by the end of week one. Likewise, $78 is planned to be spent on Outline programming requirements, and the Test activities.
- While the total PV for Activity 10 (Put into Case) is $39, no money was planned to be used on this activity by the end of week one. In other words, no work was to be done on this activity by the end of week one.

Table 10.2 Time-phased budget for Project Tweet

ID	Task	Activity Budget (PV)	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
1	Design prototype board	$468	$78	$390				
2	Order Sensors	$156		$156				
3	BreadBoard Sensors and connections	$546			$234	$312		
4	Outline programming requirements	$390	$78	$312				
5	Draft Preliminary Program	$1,092		$78	$390	$390	$234	
6	Load program and test	$156					$156	
7	Setup "Real" Twitter Account	$39					$39	
8	Develop Final Test Criteria	$78			$78			
9	Test	$780	$78	$390	$312			
10	Put into Case	$39					$39	
11	Complete Perm Install	$156					$78	$78
12	Write up Details and Post	$234						$234
		Week Total	$234	$1,326	$1,014	$702	$546	$312
		Cumulative	$234	$1,560	$2,574	$3,276	$3,822	$4,134

This view shows the amount of money that will be spent on project activities each week. This is important for managing cash flow, but, more importantly, it provides a time-phased budget that can be compared to the progress of the project as it is underway.

- While the total PV for all Activities (BAC) Project Tweet is $4,134, only $234 is planned to be spend on project work by the end of week one.

The time-phased budget shows how much is planned to be spent on the project for each time period. This can then be used as a baseline by which work progress can be measured.

Actual Costs (AC)

The Actual Costs—also know as Actual Cost of the Work Performed (ACWP)—is the easiest of the inputs to understand. AC is simply the actual cost of the activity at a given time.

Actual costs don't reflect what was planned to be spent, but rather **what was spent**. This information is obtained from the accounting department and the data is based on invoices, paychecks and receipts related to the activity. While the project manager may have been planning to spend $78 on Activity 1 by the end of week one, the accounting department may inform him or her that the actual cost (AC) at the end of week one for Activity 1 is $400 !!

However, the project manager still doesn't know if spending $400 on Activity 1 by the end of week one is good or bad, since he or she doesn't yet know how much work has been performed on Activity 1. The next basic input, earned value, will tell the project manager what percentage of the activity is completed and they will then know how well the project is progressing.

Earned Value (EV)

Earned Value—also know as budgeted cost of work performed(BCWP)—is simply the percentage completed on a task multiplied by the total planned value for that task.

EV = PV for the Activity × Percentage Complete

One thing to watch out for is that the calculation of EV is not time dependent; it uses the total PV for an activity, not the value for PV at a certain point in time as found on a time-phased budget. For example, if Activity 1 is 100% complete at the end of week one, then EV = $468 X 100%, or EV = $468

On the other hand, if no progress has been made on this activity (0% complete), then $468 X 0%, or EV = $0.00

Earning Rules

When calculating EV, project managers may have to make some trade-offs. They have to consider how much time and resources to devote to measuring the progress on an activity. In some cases, a project manager will use a professional estimator determine the percentage completed on activities. This is usually done for those activities that cost a lot of money or take a lot of time (say 80-90 days or more).

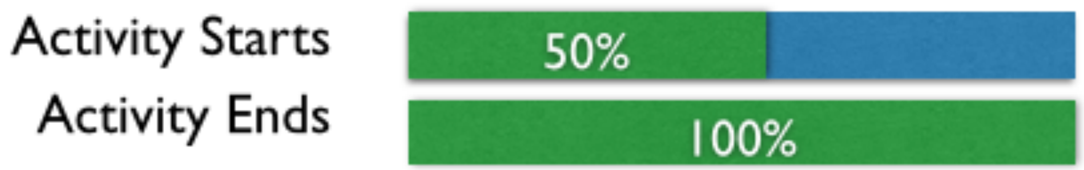
For most activities, however, it doesn't make sense to spend that much effort estimating the percentage completed. As a result, project managers have developed some guidelines, or rules, for quickly assessing the percent complete for an activity. These simple earning rules work well for small or simple projects because generally each activity tends to be fairly short in duration. Project Managers will use one of these rules to estimate the percent complete for most of their activities or work packages.

0/100 Rule

No earned value is counted for an activity until it is 100% complete.

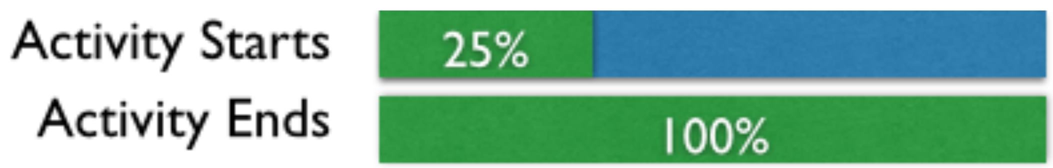
50/50 Rule

Percent complete is calculated at fifty percent when activity starts. Remaining 50% is added when activity is complete.



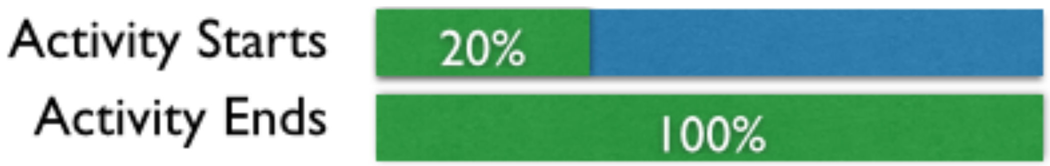
25/75 Rule

Percent complete calculated at twenty-five percent when activity starts. Remaining 75% is calculated when activity is complete.



20/80 Rule

Percent complete calculated at twenty percent when activity starts. Remaining 80% is calculated when activity is complete.



Earning rules such as a 25/75 rule or 20/80 rule are gaining favor because they assign more weight to finishing work than for starting it, but still also motivate the project team to identify when an element of work is started.

Earned Value Inputs Summary

These simple inputs can be very powerful tools when we compare our project progress with our original project plans. In the next section, we'll use these inputs to determine how our project is progressing and where it is headed.

Table 10.3 Earned Value Inputs Summary

Earned Value Basic Inputs		
Term	**Description**	**Calculation**
PV	Planned Value (Also known as BCWS – Budgeted Cost of the Work Scheduled)	PV = Planned value of the work that is scheduled in our current baseline.
BAC	Budgeted cost at completion.	BAC=TOTAL PV for Project
AC	Actual Costs (Also know as ACWP – Actual cost of the work performed)	AC= Actual Costs (Total of all invoices, labor, parts, etc).
EV	Earned Value (Also know as BCWP – Budgeted cost of the work performed)	EV= (Total Planned Value of Activity or Project) X (Percent Complete).

Section 2

Earned Value Analysis

Once the EV, AC and PV for a project's activities have been calculated. additional metrics can be calculated about the project's progress. An earned value analysis can provide information about variances in the project schedule and budget, provide an indication of overall performance on the project through various performance indices, and forecast final project costs.

Cost Variance (CV)

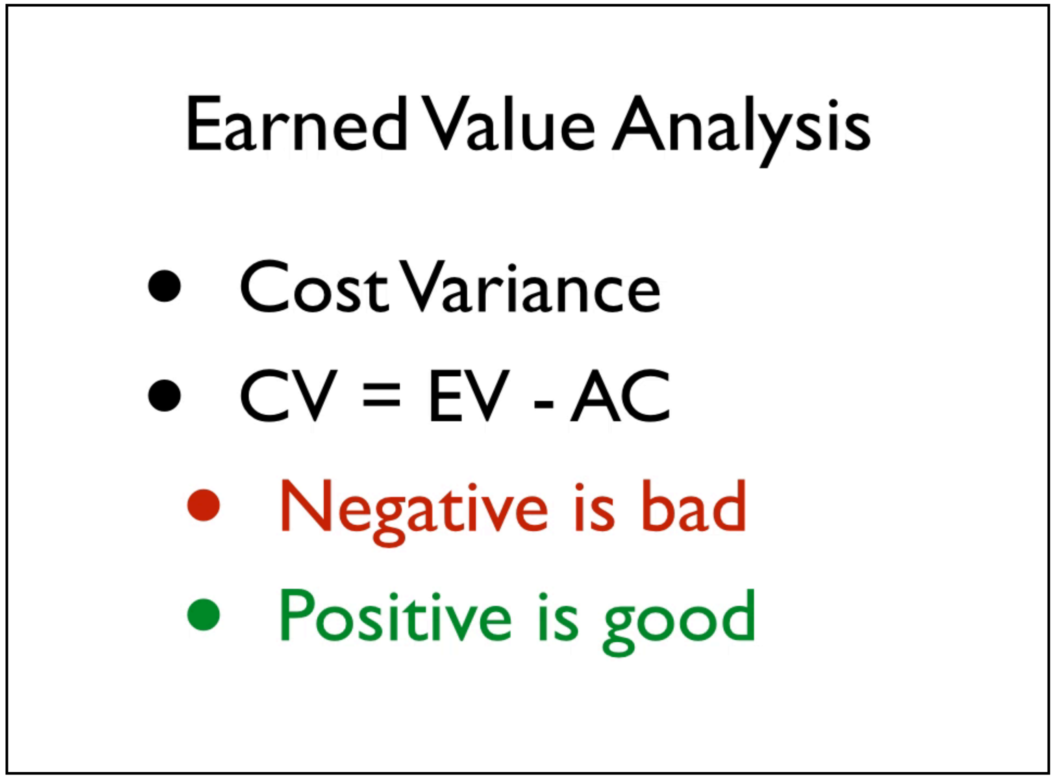
CV is the first of two basic variances that can be calculated once EV, PV and AC have been determined for an activity or project. CV is simply the Earned Value minus the Actual Costs.

$$CV = EV - AC$$

If CV is negative, that means that the project work is costing more than planned. If CV is positive, then the project work is costing less than planned.

CV can be calculated for each activity, for segments of a project (for example a deliverable or sub-deliverable) or for the entire project. Watch Video 10.1 for an explanation of how to calculate and interpret CV.

Video 10.1 Calculating and Understanding Cost Variance



You can also view this video at: http://pmf.video/video12

Schedule Variance (SV)

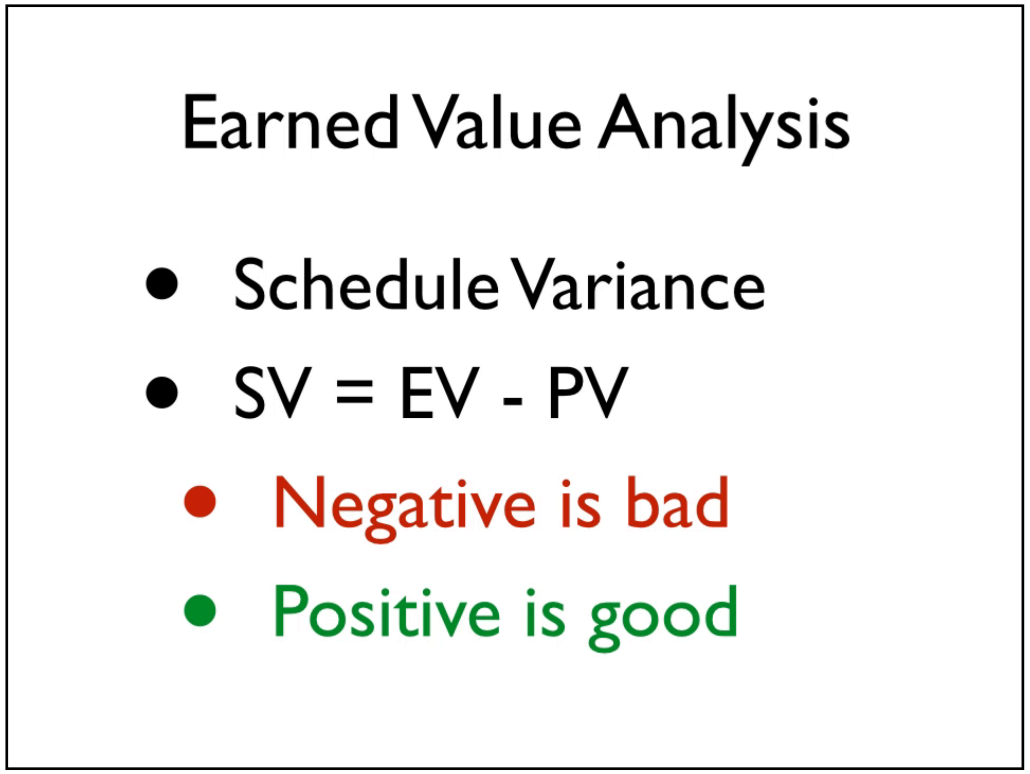
SV is the second of two basic variances that can be calculated once EV, PV and AC have been determined for an activity or project. SV is simply the Earned Value minus the Planned Value.

$$SV = EV - PV$$

If SV is negative, that means that less work has been performed than what was planned.. If SV is positive, then more work has been done than planned.

Like CV, SV can be calculated for each activity, for segments of a project (for example a deliverable or sub-deliverable) or for the entire project. Watch Video 10.2 for an explanation of how to calculate and interpret SV.

Video 10.2 Calculating and understanding Schedule Variance



You can also view this video at: http://pmf.video/video13

Using Money to Measure Time

Earned Value Analysis can be a great way to measure the efficiency of a project's schedule while the project is being executed. However, project managers need to be cautious when considering schedule metrics (SV, and SPI which will be covered shortly), as they are only a measure of how efficiently the project is using money to complete the schedule, and are only effective prior to a task's completion.

Watch Video 10.3 for an explanation of the problems with using money to measure time.

Video 10.3 Why measuring time with money can be problematic.

You can also view this video at: http://pmf.video/video14

Cost Performance Index (CPI)

While CV provides a dollar amount that reflects how much over or under the project is at a particular point in time, The Cost Performance Index (CPI) provides an indicator of the overall cost performance to date and a good idea of how the project work is trending with regard to cost performance. CPI is calculated as follows:

$$\text{CPI} = \frac{\text{EV}}{\text{AC}}$$

- A CPI that is < 1 means that the cost of completing the work is higher than planned.
- A CPI that is = 1 means that the cost of completing the work is right on plan.
- A CPI that is > 1 means that the cost of completing the work is less than planned.

Watch Video 10.4 on “Cost Performance Index” for a basic walkthrough of CPI calculations and the interpretation of the results.

Video 10.4 Cost Performance Index

You can also view this video at: http://pmf.video/video15

Schedule Performance Index (SPI)

While SV provided a dollar amount that reflected well the project is doing at turning dollars into completed activities on schedule, Schedule Performance Index (SPI) provides an indicator of the overall schedule performance to date.

Remember that there are some limitations on using money to measure time. Those limitations apply to SPI as well. To know whether a project is really behind or ahead of schedule, a project manager will also look at the planned start and finish dates, milestones, etc.

SPI is calculated as follows:

$$\mathbf{SPI} = \frac{\mathbf{EV}}{\mathbf{PV}}$$

- An SPI that is < 1 means that the project is behind schedule.
- An SPI that is $= 1$ means that the project is on schedule.
- An SPI that is > 1 means that the project is ahead of schedule.

Watch Video 10.5 on "Schedule Performance Index" for a basic introduction to SPI calculations and the interpretation of the results.

Video 10.5 Schedule Performance Index

You can also view this video at: http://pmf.video/video16

Percent Complete (PBIC and PCIC)

When reviewing the CV, SV, CPI, and SPI, it is important to know the percent of the project that is complete. If CPI is .75, but the project is only 2% complete, it might not be cause for alarm. If CPI is .75 and the project is 50% completed, then it might be time for serious re-evaluation of the baseline, and the project itself.

There are two measures for calculating the percentage of the project that is complete.

Percent Complete Index—Budget (PCIB)

PCIB is percentage of work that is complete based on baseline budget. This is the percent complete index that is used when the project manager trusts their initial project baseline. The basic earned value inputs are used to calculate PCIB:

$$\mathbf{PCIB} = \frac{\mathbf{EV}}{\mathbf{BAC}}$$

Please note that in this equation EV is the sum of EV for all activities.

Percent Complete Index—Cost (PCIC)

PCIC percentage of work that is complete based on the actual costs, which uses a revised estimate of the project costs (EAC_{re}). This index is used if the project manager has had to revise the baseline due to changes in scope, or if rolling wave planning is used, or if there some other reason why the project manager doesn't trust the project baseline costs.

$$\mathbf{PCIC} = \frac{\mathbf{AC}}{\mathbf{EAC_{re}}}$$

In this case, EAC_{re} is obtained from an estimator or some other estimation process.

Table 10.4 Earned Value Calculations Summary

Term	Description	Calculation	Interpretations
CV	Cost Variance (compares budgeted costs to the actual amount spent).	$\mathbf{CV = EV - AC}$	Negative number = over budget. Positive number = under budget.
SV	Schedule Variance (Compares the work that should have been done at this time, to the amount actually completed).	$\mathbf{SV = EV - PV}$ (Note: PV at this point in time, not total PV for activity.)	Negative number = work scheduled to be complete at this time is not done. Positive number = work NOT yet scheduled to be complete at this time has been done
CPI	Cost Performance Index. Provides a measure of the efficiency of our project in terms of budget.	$\mathbf{CPI = \frac{EV}{AC}}$	A CPI that is < 1 means that the cost of completing the work is higher than planned. A CPI that is = 1 means that the cost of completing the work is right on plan. A CPI that is > 1 means that the cost of completing the work is less than planned.
SPI	Schedule Performance Index. Provides a measure of the efficiency of our project in terms of budget.	$\mathbf{SPI = \frac{EV}{PV}}$ (Note: PV at this point in time, not total PV for activity.)	A SPI that is < 1 means that the project is behind schedule. A SPI that is = 1 means that the project is on schedule. SPI that is > 1 means that the project is ahead of schedule
PCIB	The percentage of work that is complete based on baseline budget.	$\mathbf{PCIB = \frac{EV}{BAC}}$	
PCIC	The percentage of work that is complete based on our actual costs, which uses a revised estimate of the project costs.	$\mathbf{PCIC = \frac{AC}{EAC_{re}}}$	

To Complete Performance Index (TCPI)

As we have seen, CPI provides an indicator of overall project cost performance to date. In order to know what the CPI will need to be in order for the CPI to be 1 when the project is complete, the project manager will want to find the value of the To Complete Performance Index (TCPI). TCPI is calculated as follows:

$$\mathbf{TCPI} = \frac{(\mathbf{BAC} - \mathbf{EV})}{(\mathbf{BAC} - \mathbf{AC})}$$

- A TCPI that is < 1 means that there is more budget remaining than work to be done. If the CPI is above 1, the TCPI will be below 1.
- A TCPI that is = 1 means that the project has the right amount of budget for the remaining work.
- A TCPI that is > 1 means that there is more work than budget left. If the CPI is below 1, then TCPI will be above 1.

A Trick for Remembering the Formulas.

If there is a **C** in the value that you are trying to calculate, then you will be using A**C** (which also has a **C** in it !)

For example, **C**V is the difference between EV and A**C**. And **C**PI is EV divided by A**C**.

If there is **not a C** in the product that you are trying to produce with your equation, then you use PV.

Video 10.6 Your reaction to figuring out that **C**PI and **C**V compares EV with A**C.** And that the Cs connect everything together in the universe. And anything without a C uses PV.

You can also view this video at: http://pmf.video/video17

Forecasting Costs (ETC, EAC, VAC)

There are several additional values that can be calculated to answer some questions about the future of a project, such as:

- If things continue as they have been, how much will it cost to complete the remaining work?
- If things continue as they have been, what will be the final project cost?
- How much will the projected final project cost vary from our current project budget?

Estimate to Complete (ETC)

It is fairly simple to calculate the cost to complete the remaining work on a project (assuming the performance on the rest of the project will be the same is the project has experienced thus far). In other words, what the remaining work will cost if the current CPI holds. This is known as the Estimate to Complete (ETC) and it is calculated as follows:

$$\mathbf{ETC} = \frac{(\mathbf{BAC} - \mathbf{EV})}{\left(\frac{\mathbf{EV}}{\mathbf{AC}}\right)}$$

Since the denominator of the equation, EV divided by AC, is equal to CPI, then ETC can also be expressed as:

$$\mathbf{ETC} = \frac{(\mathbf{BAC} - \mathbf{EV})}{(\mathbf{CPI})}$$

Estimate At Completion (EAC)

Now that the ETC has been generated, it can be added to the actual costs of the project to date to provide an estimate of what the total cost will be when the project is complete:

$$\mathbf{EAC} = \mathbf{AC} + \mathbf{ETC}$$

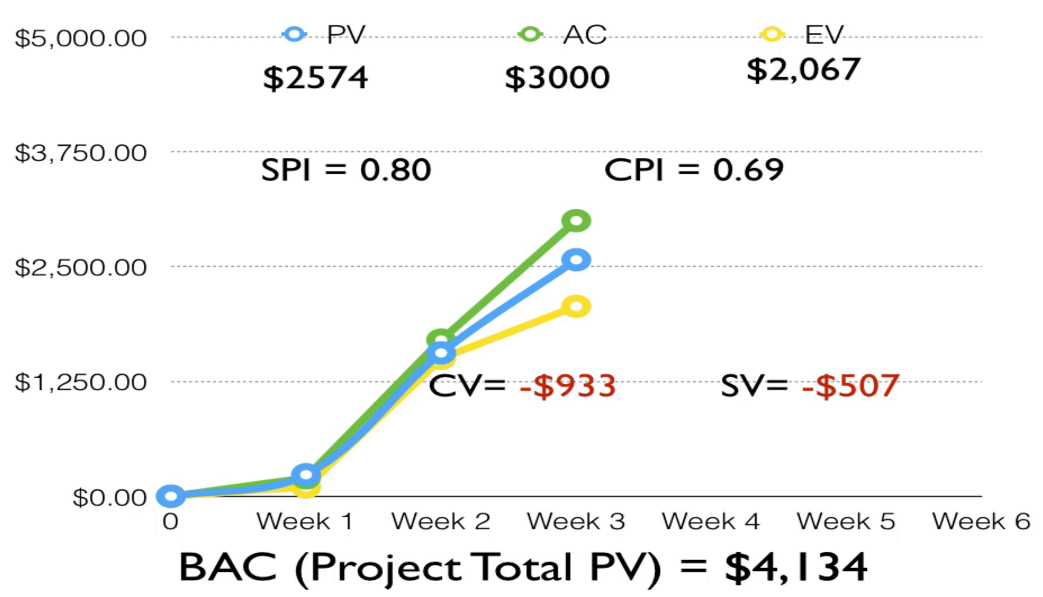
Variance At Completion

Variance at Completion is just the difference between what we had budgeted (the BAC) and the current estimate at completion (EAC).

$$\mathbf{VAC} = \mathbf{BAC} - \mathbf{EAC}$$

Watch Video 11.7 for an overview and example of how these forecasting tools are used.

Video 10.7 Forecasting Costs (ETC, EAC, VAC)



You can also view this video at: http://pmf.video/video18

Table 10.5 EVA Forecasting metrics

Term	Description	Calculation
ETC	Estimate to Complete. What it will cost to complete the remaining work if things keeps going as they have up to this point.	$\mathrm{ETC} = \frac{\left(\frac{\mathrm{BAC}}{\mathrm{EV}}\right)}{\left(\frac{\mathrm{EV}}{\mathrm{AC}}\right)}$
EAC	Estimate At Completion. What our project will cost if things keeps going as they have up to this point.	$\mathrm{EAC} = \mathrm{AC} + \mathrm{ETC}$
VAC	Variance At Completion Variance at Completion is just the difference between what we had budgeted (the BAC) and the current estimate at completion (EAC).	$\mathrm{VAC} = \mathrm{BAC} - \mathrm{EAC}$

Chapter 11

Appendix

Section 1

RoadMap

Version 0.5 (this version) of Project Management Fundamentals was officially released on Oct 10, 2016. As mentioned in the preface, the creation of this text is an iterative project. **And one that needs a lot of feedback from the users of this text!** Presented in this section is the current roadmap of the features that will be added before the .06 release (mid to late Jan 2017). Please provide your feedback on other features that should be added in the .06 and subsequent releases by visiting: https://www.pmf.education/roadmap/

New Chapters

New Chapter: Risk Management

New Section: Defining Risks

Project Risk vs. Operational Risk
Risk Identification
Risk Register
Quantitative Risk Assessment
Qualitative Risk Assessment

New Section: Managing Risks

Risk Management Strategies
Managing negative project risk:

- Avoid
- Accept
- Minimize (Mitigate)
- Transfer

Managing positive project risk:

- Accept
- Enhance
- Exploit

New Chapter: Change Management

New Section: Managing Change

Change Requests
Corrective Action
Preventative Action
Integrated Change Control
Change Control Board
Change Control Process

New Chapter: Agile Project Management

New Section: Agile Principals

New Section: Scrum

New Section: Extreme Programming

Updates to Existing Chapters

Existing Chapter: Reducing Project Time Chapter

New Section: Crashing

Provide detail about crashing so that students don't have to rely only on video

Existing Chapter: Project Networks

New Section: Resource Loading and Leveling

Resource Constraint
Resource Loading
Resource Leveling

New Section: Finalizing our Schedule

Modeling
Monte Carlo Analysis
Critical Chain Analysis
Control Schedule
Reestimating

Existing Chapter: Project Management and the Organization

New Section: Organizational Culture

What is Organizational Culture
How culture affects project management
Tools are to assess an organization's culture