

# How to Make Reliable Project Schedule and Cost Estimates

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# HOW TO MAKE RELIABLE SCHEDULE AND COST ESTIMATES

## MAKING RELIABLE SCHEDULE ESTIMATES

One of the most challenging aspects of managing projects today is that of including uncertainties in our estimates, specifically with schedule uncertainties (task durations, task efforts, and task costs).

### Deterministic Estimating

Consider a project manager who asks a software engineer how long it will take to do the necessary software debugging. The software engineer may be thinking anywhere from 14 days to 35 days, but since the project manager is asking for a single estimate, the engineer may frustratingly say, “25 days.” In taking this approach the project manager has failed to take into account the uncertainties related to the software debugging task, and has mistakenly used a single-point estimating technique referred to as *deterministic estimating*.

If deterministic estimates are made throughout the entire project schedule, the project completion date will be inaccurate and overly optimistic, resulting in misplaced expectations. Everyone will assume the estimated project completion date can be met with a high degree of confidence. In actuality, the chances of meeting the estimated project completion date will be 50% or less. The same can occur when estimating task efforts (labor hours), and task costs. Inaccurate estimates result when using the deterministic approach.

### Stochastic Estimating

In order for uncertainties to be included in the project estimates it is necessary to take into account an optimistic estimate (o), a pessimistic estimate (p), and a most-likely estimate (m). This approach is referred to as *stochastic*, or *statistical* estimating, and is the correct technique to use when developing what is known today as a PERT (Program Review and Evaluation Technique)<sup>1</sup> network for project scheduling.

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<sup>1</sup> *Program Review and Evaluation Technique PERT* (Program Evaluation and Review Technique) is an event-oriented network analysis technique used to estimate project duration when there is a high degree of uncertainty with individual activity estimates.

Using this approach the project manager asks the software engineer for an optimistic estimate (o), a pessimistic estimate (p), and a most-likely estimate (m). The engineer now provides the three needed estimates of 14 days, 25 days, and 35 days. Using this technique the project manager can now determine the project's true duration at a desired level of confidence, such as 90%. This is accomplished by using the equation below:

$$D = \sum T_e + Z\sqrt{\sum \sigma^2}$$

Where:

$\sum T_e$  = the sum of all critical path expected times

$\sum \sigma^2$  = the sum of all critical path variances

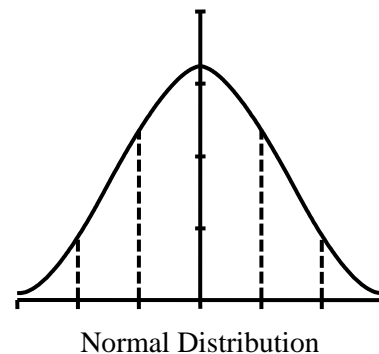
Z = the number of standard deviations of a normal distribution  
(the standard normal deviate)

These equations are based on a *normal distribution* which is deemed to be the best model for making these types of estimates. Using project estimates (task durations, task hours, or task costs), such as those in the following table, the estimated value at a given probability can be made as shown below:

$$D = \sum T_e + Z\sqrt{\sum \sigma^2}$$

$$D = 463 + 1.2810\sqrt{168.4}$$

$$D = 480$$



It can be noted that the sum of the most-likely estimates may not always be equal to the sum of the expected times ( $\sum T_e$ ). This is because the most-likely estimate may not always be at the mid-point between the pessimistic and optimistic estimates. Regardless of the shape formed by the data values of the estimates, the shape of the values making up the sampling distribution of the expected times will approach a normal distribution based on the *central limit theorem*, if the sampling size is sufficiently large (usually 30 or greater). When the sampling size is less than 30, and the Central Limit Theorem cannot be invoked, a t-distribution must be used.<sup>2</sup>

<sup>2</sup> Louise J. Clark, and E. Milewski, *The Essentials of Business Statistics I*, (Research and Education Association: Piscataway, N.J. 1991).

Sample No.	Optimistic (o)	Most Likely (m)	Pessimistic (p)	Expected Value (T <sub>e</sub> )	Std Dev. (σ)	Variance (σ <sup>2</sup> )
1	14	25	35	25	3.5	12.3
2	20	20	28	21	1.3	1.8
3	5	8	9	8	0.7	0.4
4	7	10	14	10	1.2	1.4
5	2	5	7	5	0.8	0.7
6	8	12	15	12	1.2	1.4
7	2	5	8	5	1.0	1.0
8	10	15	22	15	2.0	4.0
9	6	8	9	8	0.5	0.3
10	4	7	9	7	0.8	0.7
11	10	12	15	12	0.8	0.7
12	8	16	18	15	1.7	2.8
13	5	8	10	8	0.8	0.7
14	10	15	22	15	2.0	4.0
15	6	8	9	8	0.5	0.3
16	4	7	9	7	0.8	0.7
17	10	12	15	12	0.8	0.7
18	8	16	18	15	1.7	2.8
19	5	8	10	8	0.8	0.7
20	10	18	28	18	3.0	9.0
21	4	4	4	4	0.0	0.0
22	25	35	50	36	4.2	17.4
23	4	16	38	18	5.7	32.1
24	2	9	15	9	2.2	4.7
25	4	7	9	7	0.8	0.7
26	10	12	15	12	0.8	0.7
27	8	16	18	15	1.7	2.8
28	7	10	14	10	1.2	1.4
29	2	5	7	5	0.8	0.7
30	8	12	15	12	1.2	1.4
31	2	5	8	5	1.0	1.0
32	10	15	22	15	2.0	4.0
33	25	35	50	36	4.2	17.4
34	4	16	38	18	5.7	32.1
35	2	9	15	9	2.2	4.7
36	4	7	9	7	0.8	0.7
37	10	12	15	12	0.8	0.7
Total (Σ)				463		168.4

Table 1: Project Estimates Example

When estimating the project's true duration it will be necessary to use only the critical-path tasks. However, when estimating the project's total cost, or total effort (labor hours), it will be necessary to consider *all* project tasks.

*A Word of Caution.* The three estimates provided by the software engineer were based on her knowledge, experience and judgment, and are referred to as *subjective probability estimates*. It therefore stands to reason that the accuracy of a stochastic estimate will be dependent upon a well-founded estimate for the three cases (*o, m, and p*). If inaccurate estimates are provided, due to inexperience, lack of knowledge, or simply a sloppy estimate, an inaccurate final estimate will result. In other words, garbage in, garbage out. It is imperative that the project manager make every effort to obtain the best possible estimates when dealing with uncertainties.

## **MAKING RELIABLE COST ESTIMATES**

Many corporations today are realizing that effective management of a project budget can only happen when the project manager is given the responsibility for estimating and managing project costs. Since most project managers have technical backgrounds, they often lack the ability to accurately estimate and manage project costs. The Total Project Cost (TPC) is usually the summation of both direct costs and indirect costs.

### Types of Direct Costs

- Direct labor costs: charged directly to the project.
- Fixed costs: do not change regardless of the size of the project.
- Operating costs: associated with project unique equipment of material.
- Sunk costs: unrecoverable costs.
- Standard costs: associated with common tasks.
- Project material parts purchased off-the-shelf (OTS).
- Project subcontract costs: associated with outsourcing.
- Functional costs: associated with functional, level-of-effort support.

### Types of Indirect Costs (Also called "burdened costs")

- Overhead costs: typically facilities, insurance, benefits, security, etc.
- General & Administrative (G&A): corporate executives, attorneys.
- Apportioned costs: associated with supervision of hourly employees and project support organizations.
- Capital assets: common equipment owned by the corporation.
- Bid & proposal costs: for pursuing outside contract business.

### Level of Effort vs. Discrete Costs

Discrete costs are based on project activities that have a discrete beginning and end. Level of effort estimates are based on functional support where discrete tasks cannot be assigned. Examples of LOE support would be project managers and project consultants who are made available on an as needed basis.

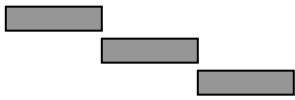

	Discrete Costs	Level of Effort Costs
Cost Basis	Discrete activities	Functional support
Cost Distribution	Discrete activities	Uniformly, over support period
Applied to:	Project members	Project managers, consultants
Schedule Symbols		

Table 2: Discrete vs. Level-of-Estimate Costs

### **How to Make Quick Cost Estimates**

Quick cost estimates are made when there is only a few days to make them, and when go/no-go decisions must be made on pursuing a new product or a major change to an existing product. The three techniques often used to make quick cost estimates are, 1) rough order-of-magnitude estimates, 2) budgetary estimates, and 3) analogous estimates.

Method	Typical Response Time	Information Basis	Project Phase	Lowest WBS Level	Estimate Accuracy
ROM	1 to 2 days	Verbal, Conceptual	Initiation	Top level	-25% to 75%
Budgetary	2 to 5 days	Preliminary requirements	Initiation, Planning	2 <sup>nd</sup> Level	-10% to +25%
Analogous	2 to 5 days	Preliminary requirements	Initiation, Planning	2 <sup>nd</sup> or 3 <sup>rd</sup> Level	Depends on accuracy of the comparison formula

Table 3: A Comparison of Quick Cost Estimating Methods

*Rough Order-of-Magnitude (ROM) Cost Estimates.*<sup>3</sup> Sometimes called a “ball park estimate” is used when little is known about the specifics of a project but when a decision must be made based on an approximate estimate. Typically, the estimate is based on a verbal description of the item to be estimated. ROM estimates are usually needed within a few dates of the request, and should always be submitted as range estimates based on the assumptions made at the time of the request.

Estimated Labor Hours	3,500
Burdened Composite Labor Rate	\$250/hour
Estimated Labor Cost	\$875,000
Estimated Material & Subcontract Costs	\$125,000
Total Estimated Cost	\$1,000,000
ROM Minimum Estimate (-25%)	\$750,000
ROM Maximum Estimate (+75%)	\$1,750,000

Table 4: ROM Estimate Example

Certain precautions must be followed when submitting ROM estimates because the basis of the estimate is usually in a state of change, and the estimator may inadvertently be held responsible for an estimate made on Monday but the concept had evolved into something much greater several days later. These precautions include the following:

- Give a ROM range rather than a specific number.
- Submit the estimate verbally whenever possible.
- Along with the ROM estimate include: a) the assumptions existing at the time of the request, b) all data/information used as the estimate basis, and c) how long the estimate is valid.

*Budgetary Cost Estimating.* When more information is available, compared to that used for a ROM estimate, a tighter estimate can be made. Even though more information may be available it is still in a preliminary state. Budgetary estimates are often called for when financial commitments must be made to new projects, or major changes to existing projects. It is not uncommon for budgetary estimate response times to be between one to two days. Examples of budgetary estimates can be found at [www.projectmgt.com](http://www.projectmgt.com).

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<sup>3</sup> “Rough Order-of-Magnitude” estimates were formerly called “WAG”, or “SWAG” estimates. These later terms are now obsolete.

*Analogous (Parametric) Estimating.* Analogous estimating means that you use the actual time frame from a previous, similar project as the basis for estimating the time frame for the current project. The underlying premise is that *present* project is analogous to a *past* project. Because you know how long that past project took, you can estimate how long the present project will take. Analogous estimating is used when little information is known about the current potential project or when two projects appear similar. Of course, if they appear similar but, in fact, are not, the estimate will be inaccurate. Analogous estimations are good for “ball-park figures” but not for precise estimations of a project or timeline development.

The problem with using analogous estimations is that one project is rarely exactly like another. Even when projects are similar to each other they usually vary in substantial ways. The best time to use this type of estimation is when you need a quick “guestimation” in one or two days, and a defensible comparison factor can be generated based on such aspects as:

- Lines of code
- Physical similarities
- Degree of testing
- Documentation
- Design complexity

## How to Make Detailed Cost Estimates

After the project is authorized the project manager can gather needed personnel to make a more definitive cost estimate. These estimates are usually made by loading needed resources into the project schedule. Because many estimators tend to “pad” their estimates it is vital that they submit basis-of-estimate calculations which can provide realistic visibility to the project manager who can then make a reasonable judgment to the estimate accuracy. Example 1 below shows an estimate of 300 hours which could include padding that might not be visible to the project manager. Example 2 shows a basis of estimate broken down into lower levels of granularity making it easier for the project manager to evaluate.

Example 1	Example 2
<p>It is estimated that it will take 300 hours to prepare drawings for the Drive Motor Assembly Mounting Bracket.</p> <p>Total Direct Labor = 300 hours</p>	<p>Estimated number of drawing sheets for the Drive Motor Assembly Mounting Bracket = 26 sheets.</p> <p>12 sheets at 8 hrs/sheet = 96 hours (labor category: “Designer”).</p> <p>14 sheets at 10 hrs/sheet = 140 hours (labor category: “Sr. Engineer”).</p> <p>Review/approve drawings at 2 hrs/sheet = 52 hours (labor category: “Drawing Checker”).</p> <p>Total Direct Labor = 96 + 140 + 52 = 288 hours</p>

*Project Cash Flow Table.* When all discrete and functional (level-of-effort) resources have been loaded into the project schedule a project cash flow table can be produced. Most project schedule applications can produce this table automatically. Cash flow tables are of interest to those who fund the project. Large funding variations may require a limit reconciliation with the customer or the performing organization before being deemed acceptable. Project funding should accommodate an incremental (step-function) cash flow possibly realizing a management reserve at the end of the project.<sup>4</sup>

ACTIVITY	1Q2007	2Q2007	3Q2007	4Q2007	1Q2008	2Q2008	3Q2008	4Q2008	TOTAL
Project Manager (Level-of-Effort)	\$22,500	\$22,500	\$22,500	\$24,750	\$24,750	\$24,750	\$24,750	\$27,000	\$193,500
Requirements Planning									
Review Existing Systems	\$70,000								\$70,000
Perform Work Flow Analysis	\$43,000	\$22,000							\$65,000
Model Process	\$24,500	\$34,770							\$59,270
Identify User Requirements			\$54,000						\$54,000
Identify Performance Requirements			\$42,000						\$42,000
Identify Interface Requirements			\$54,000	\$33,000					\$87,000
Prepare Software Requirements Specification				\$66,000	\$37,000				\$103,000
Software Requirements Review				\$79,800	\$12,760				\$92,560
Preliminary Design									
Prepare Functional Designs					\$112,330				\$112,330
Design Segment #1					\$54,900				\$54,900
Design Segment #2					\$32,000	\$49,000			\$81,000
Design Segment #3						\$67,800			\$67,800
Prepare Interface Control Documents						\$11,000	\$28,000		\$39,000
Document Interface #1							\$21,000		\$21,000
Document Interface #2								\$22,000	\$22,000
Prepare Software Test Plan								\$33,000	\$33,000
Define Testing Phases & Goals								\$17,800	\$17,800
TOTAL	\$160,000	\$79,270	\$172,500	\$203,550	\$273,740	\$152,550	\$73,750	\$99,800	\$1,215,160

Table 5: Project Cash Flow Table Example

*Cost Estimating Pitfalls to Avoid.* Following are oversights that must be avoided when making project cost estimates.

- Poorly defined requirements and work scope.
- Omissions of scope.
- Estimating costs too rapidly.
- Not using consistent standard costs.
- Not using detailed basis-of-estimate calculations.
- Overly optimistic task durations.
- Inaccurate commercial off-the-shelf (COTS) parts procurement lead-times.

<sup>4</sup> PMBOK, Paragraph 7.2.3.2.

- Using the wrong labor category.
- Not including risk mitigation costs.
- Failing to use forward pricing rates.

## HOW TO ADJUST FOR THE TIME-VALUE OF MONEY

Most project managers know that the value of money changes with time, and they know how to estimate project costs, yet many fail to tie the two together. As a consequence, the project cost estimate is based on *constant dollars*<sup>5</sup> but accrued in *then dollars*.<sup>6</sup> They must then face an embarrassing predicament of having accost overrun even if everything went perfectly as planned.

To avoid this mistake project managers must be capable of estimating future values and present values for project costs. Future value (FV) is what an amount today is worth at a future point in time. Present value (PV): The current value of a future cash flow.

### How to Calculate Future Values

$$\text{Future Value} = \text{PV} (1+i)^n$$

Where:

PV = present value

n = number of compounding periods

i = discount rate at which money is affected over time (interest, inflation, etc.)

*Example.* You have estimated that your project will cost \$7 Million if it begins today. Your boss calls you to say that it will be delayed 5 years; how much will the same project cost with a discount rate of 4% per year?

$$\text{Future Value} = \text{PV} (1 + i)^n = \$7,000,000 (1 + 0.04)^5 = \$8,500,000$$

### How to Calculate Present Values

$$\text{Present Value} = \text{FV}/(1+i)^n$$

Where:

FV = future value

n = number of compounding periods

i = discount rate at which money is affected over time (interest, inflation, etc.)

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<sup>5</sup> Constant dollars: The term specifically refers to dollars whose present value is linked to a given year—dollars that do not incorporate the impact of inflation.

<sup>6</sup> Then dollars: A cash flow that explicitly incorporates the impact of inflation.

*Example:* Your company has invested \$100,000 in a new product which is sold to an OEM<sup>7</sup> firm. The OEM firm now proposes the following payment schedule saying it will provide your company with a lucrative gain of 50%.

End of Year	Payment
5	\$10,000
6	\$20,000
7	\$30,000
8	\$40,000
9	\$50,000
Total	\$150,000

Is your company really getting a 50% return-on-investment? This is answered by bringing all future values to their present value using the “PV” equation as shown below. As can be seen, the future value of all payments is \$72,756, far less than the initial \$100,000 investment.<sup>8</sup> This payment schedule reveals an actual loss.

End of Year	Payment (FV)	(1+i) <sup>n</sup>	Present Value
5	\$10,000	1.61	\$6,210
6	\$20,000	1.77	\$11,300
7	\$30,000	1.95	\$15,380
8	\$40,000	2.14	\$18,680
9	\$50,000	2.36	\$21,186
Total	\$150,000		\$72,756

Is your company getting a good ROI if it targets a return of 10%? In other words, what should the FV of \$100,000 be at the end of the 9<sup>th</sup> year at 10%?

$$FV = \$100,000 \times (1.10)^9 = \$235,795$$

Since all future value payments total \$150,000, it can be seen again that this payment schedule will not produce a desired return-on-investment of \$100,000.

*Other Financial Equations.* Other financial equations that project managers should be familiar with are as follows:

- Net Present Value (NPV) =  $\sum \text{Benefits}_{PV} - \sum \text{Costs}_{PV}$
- Benefit/Cost Ratio =  $\sum \text{Benefits}_{PV} / \sum \text{Costs}_{PV}$
- Return on Investment (ROI) =  $\text{NPV} * 100 / \sum \text{Costs}_{PV}$

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<sup>7</sup> An original equipment manufacturer (frequently abbreviated "OEM") is a company that builds products or components which are used in products sold by another company (often called a value-added reseller, or VAR). An OEM will typically build to order based on designs of the VAR. For example, a hard drive in a computer system may be manufactured by a corporation separate from the company that markets and sells the computer.

<sup>8</sup> Even if the payments are reinvested at 10%, the total PV would only be \$84,476.