

COCOMO (COnstructive COst MOdel)

COCOMO is a model for estimating software costs, which aids in forecasting the effort, expenses, and timeline necessary for a software development project. Created by Barry Boehm in 1981, COCOMO employs a mathematical equation that is based on the size of the software project, usually quantified in lines of code (LOC).

Basically, COCOMO helps in estimating:

- **Effort** (person-months required to complete the project)
- **Time** (duration required to complete the project)
- **Cost** (total budget needed)

The COCOMO model consists of three different levels or modes:

1. Basic COCOMO

This mode is used for early-stage project estimates and focuses on estimating effort based on lines of code (LOC). It uses a simple formula to calculate the effort required for a project, taking into account the project size in KLOC (thousands of lines of code).

$$\begin{aligned} Effort &= a * (KLOC)^b \\ Time &= c * (Effort)^d \\ PeopleRequired &= \frac{Effort}{Time} \end{aligned}$$

Where **Effort** is measured in **person-months**.

Time is measured in **months**.

KLOC is the size of the software in thousands of lines of code.

a,b,c,d are constants that depend on the type of project.

Types of Software Projects:

COCOMO classifies software projects into **three categories** based on complexity:

Software Type	Description	a	b	c	d
Organic	Small, simple projects with well-understood requirements (e.g., payroll systems, inventory management)	2.4	1.05	2.5	0.38
Semi-detached	Medium-sized projects with moderate complexity and mixed experience teams (e.g., database systems, OS utilities)	3.0	1.12	2.5	0.35
Embedded	Complex projects with strict constraints and real-time processing (e.g., military software, aircraft control systems)	3.6	1.20	2.5	0.32

Example: For developing an **Organic** project with **10,000 LOC** (10 KLOC).

$$Effort = 2.4 * (10)^{1.05} = 2.4 * 10.25 = 24.6 \text{ person-months}$$

$$\text{Time Required, } Time = 2.5 * 5.4 = 13.5 \text{ months}$$

$$\text{People Required} = People = \frac{24.6}{13.5} = 1.82 \approx 2$$

Thus, the project will take **13.5 months** with **2 developers**.

2. Intermediate COCOMO Model

The Intermediate COCOMO Model improves the estimation by considering 15 cost drivers that affect development, categorized into four groups:

Category	Factors
Product Attribute	Required software reliability, database size, complexity
Hardware Attribute	Execution time, memory, volatility
Personnel Attribute	Analyst capability, programmer experience, team cohesion
Project Attribute	Software tools, development schedule, team constraints

The modified formula becomes:

$$Effort = a * (KLOC)^b * EAF$$

Where EAF (Effort Adjustment Factor) is a product of all the cost drivers, typically ranging from 0.7 (efficient) to 1.5 (complex projects).

Example: Using our previous example (Organic project with 10 KLOC), but now considering an **EAF of 1.2**

$$Effort = 2.4 * (10)^{1.05} * 1.2 = 24.6 * 1.2 = 29.52 \text{ person-months}$$

So, the new effort is **29.52 person-months** instead of **24.6**, accounting for complexity.

3. Detailed COCOMO Model

The model contains all qualities of both Basic COCOMO and Intermediate COCOMO techniques for each Software Engineering process. The model considers each project's development phase (analysis, design, and so on). It is a complex model, considering the fact that it considers more parameters. Here, the whole software is parted into different modules and then the COCOMO model is applied to all the modules separately. Finally, the efforts are joined to calculate the total result. The six phases of the Advanced/Detailed COCOMO Model are:

- Planning and Requirements
- System Design
- Detailed Design
- Module Code and Testing
- Integration and Testing
- Cost Constructive Model
- Maintenance

This model is highly accurate because it considers the complexity of each phase separately.

Example: developing a semi-detached software project (medium complexity) with 50,000 LOC (50 KLOC).

$$\text{From the Basic COCOMO model, } Effort = a * (KLOC)^b$$

For a semi-detached project: $a=3.0$, $b=1.12$

$$Effort = 3.0 * (50)^{1.12} = 3.0 * 61.58 = 184.74 \text{ person months}$$

Now, we apply an Effort Adjustment Factor (EAF) based on cost drivers. Let the different ratings for the 15 cost drivers (like team experience, complexity, and tools), leading to an EAF of 1.15.

$$AdjustedEffort = 184.74 * 1.15 = 212.45 \text{ person-months}$$

For phase-wise effort distribution:

In Detailed COCOMO, effort is distributed across the different phases of software development be:

Phase	Percentage of Total Effort	Effort (person-months)
Planning & Requirements	10%	$212.45 \times 0.10 = 21.25$
System & Software Design	25%	$212.45 \times 0.25 = 53.11$
Coding & Unit Testing	40%	$212.45 \times 0.40 = 84.98$
Integration & Testing	20%	$212.45 \times 0.20 = 42.49$
Maintenance	5%	$212.45 \times 0.05 = 10.62$

Thus, the **effort breakdown** looks like this:

- Planning & Requirements: 21.25 person-months
- Design: 53.11 person-months
- Coding & Unit Testing: 84.98 person-months
- Integration & Testing: 42.49 person-months
- Maintenance: 10.62 person-months

The time required to complete the project is calculated as: $Time = c * (Effort)^d$

For a semi-detached project: $c=2.5$, $b=0.35$

$$Time = 2.5 * (212.45)^{0.35} = 2.5 * 7.82 = 19.55 \text{ months}$$

$$TeamSize = \frac{212.45}{19.55} = 10.86 \approx 11$$