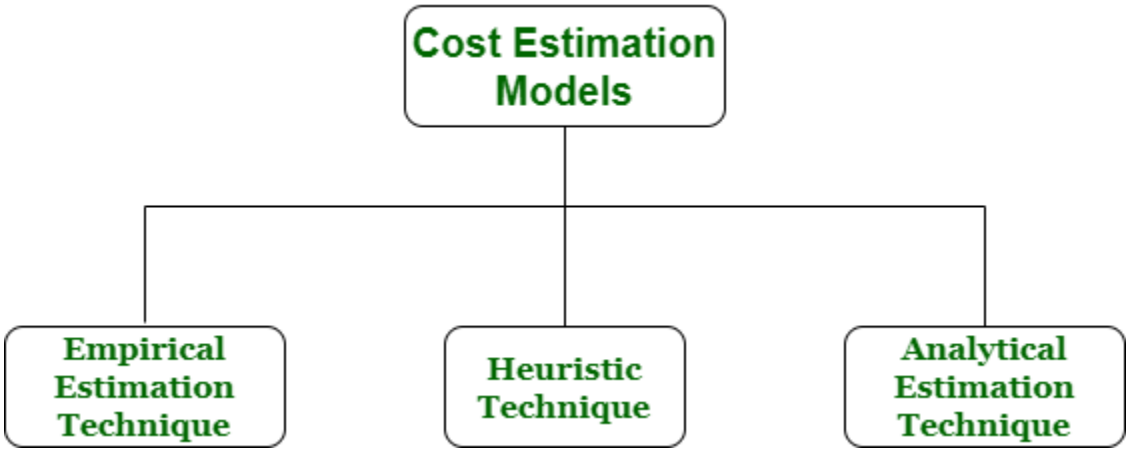
Cost Estimation Models In Software Engineering

- ***Cost estimation*** simply means a technique that is used to find out the cost estimates.

- The cost estimate is the financial spend that is done on the efforts to develop and test software in Software Engineering.

- Cost estimation models are some mathematical algorithms or parametric equations that are used to estimate the cost of a product or a project.

- Various techniques or models are available for cost estimation, also known as Cost Estimation Models as shown below :



- ***Empirical Estimation Technique***

  Empirical estimation is a technique or model in which empirically derived formulas are used for predicting the data that are a required and essential part of the software project planning step.

- These techniques are usually based on the data that is collected previously from a project and also based on some guesses, prior experience with the development of similar types of projects, and assumptions.

- It uses the size of the software to estimate the effort.

- In this technique, an educated guess of project parameters is made.

- Hence, these models are based on common sense.

- The structure of empirical estimation models is a formula, derived from data collected from past software projects, that uses software size to estimate effort.

- Size, itself, is an estimate, described as either lines of code (LOC) or function points (FP).

COCOMO - An Empirical Estimation Model for Effort

- Boehm proposed COCOMO (Constructive Cost Estimation Model) in 1981.
- COCOMO is one of the most generally used software estimation models in the world.
- COCOMO predicts the efforts and schedule of a software product based on the size of the software.

The necessary steps in this model are:

1. Get an initial estimate of the development effort from evaluation of thousands of delivered lines of source code (KDLOC).
2. Determine a set of 15 multiplying factors from various attributes of the project.
3. Calculate the effort estimate by multiplying the initial estimate with all the multiplying factors i.e., multiply the values in step1 and step2.

The initial estimate (also called nominal estimate) is determined by an equation of the form used in the static single variable models, using KDLOC as the measure of the size. To determine the initial effort Ei in person-months the equation used is of the type is shown below

$$Ei=a*(KDLOC)b$$

The value of the constant a and b are depends on the project type.

In COCOMO, projects are categorized into three types:

1. Organic
2. Semidetached
3. Embedded

1.**Organic**: A development project can be treated of the organic type, if the project deals with developing a well-understood application program, the size of the development team is reasonably small, and the team members are experienced in developing similar methods of projects. **Examples of this type of projects are simple business systems, simple inventory management systems, and data processing systems.**

2. **Semidetached:** A development project can be treated with semidetached type if the development consists of a mixture of experienced and inexperienced staff. Team members may have finite experience in related systems but may be unfamiliar with some aspects of the order being developed. **Example of Semidetached system includes developing a new operating system (OS), a Database Management System (DBMS), and complex inventory management system.**

3. **Embedded:** A development project is treated to be of an embedded type, if the software being developed is strongly coupled to complex hardware, or if the stringent regulations on the operational method exist. **For Example: ATM, Air Traffic control**.

For three product categories, Bohem provides a different set of expression to predict effort (in a unit of person month)and development time from the size of estimation in KLOC(Kilo Line of code) efforts estimation takes into account the productivity loss due to holidays, weekly off, coffee breaks, etc.

According to Boehm, software cost estimation should be done through three stages:

1. **Basic Model**
2. **Intermediate Model**
3. **Detailed Model**

1. **Basic COCOMO Model**: The basic COCOMO model provide an accurate size of the project parameters. The following expressions give the basic COCOMO estimation model:

$$\textbf{Effort} = a_1 * (KLOC)^{a_2} \ PM$$

$$\textbf{Tdev} = b_1 * (efforts)^{b_2} \ Months$$

Where

KLOC is the estimated size of the software product indicate in Kilo Lines of Code,

a_1, a_2, b_1, b_2 are constants for each group of software products,

Tdev is the estimated time to develop the software, expressed in months,

Effort is the total effort required to develop the software product, expressed in **person months (PMs)**.

Estimation of development effort

For the three classes of software products, the formulas for estimating the effort based on the code size are shown below:

Organic: Effort = 2.4(KLOC) 1.05 PM

Semi-detached: Effort = 3.0(KLOC) 1.12 PM

Embedded: Effort = 3.6(KLOC) 1.20 PM

Estimation of development time

For the three classes of software products, the formulas for estimating the development time based on the effort are given below:

Organic: Tdev = 2.5(Effort) 0.38 Months

Semi-detached: Tdev = 2.5(Effort) 0.35 Months

Embedded: Tdev = 2.5(Effort) 0.32 Months

From the effort estimation, the project cost can be obtained by multiplying the required effort by the manpower cost per month. But, implicit in this project cost computation is the assumption that the entire project cost is incurred on account of the manpower cost alone.

Example1: Suppose a project was estimated to be 400 KLOC. Calculate the effort and development time for each of the three model i.e., organic, semi-detached & embedded.

Solution: The basic COCOMO equation takes the form:

$$Effort=a_1*(KLOC)\ a_2\ PM$$

$$Tdev=b_1*(efforts)b_2\ Months$$

Estimated Size of project= 400 KLOC

(i)Organic Mode

$$E=2.4*(400)1.05 = 1295.31PM$$

$$D = 2.5 * (1295.31)0.38 = 38.07\ PM$$

(ii)Semidetached Mode

$$E=3.0*(400)1.12 = 2462.79PM$$

$$D = 2.5 * (2462.79)0.35=38.45\ PM$$

(iii) Embedded Mode

$$E = 3.6 * (400)1.20 = 4772.81\ PM$$

$$D = 2.5 * (4772.8)0.32 = 38\ PM$$

Example2: A project size of 200 KLOC is to be developed. Software development team has average experience on similar type of projects. The project schedule is not very tight. Calculate the Effort, development time, average staff size, and productivity of the project.

Solution: The semidetached mode is the most appropriate mode, keeping in view the size, schedule and experience of development time.

Hence $E=3.0(200)1.12=1133.12PM$

$D=2.5(1133.12)0.35=29.3PM$

$$\text{Average Staff Size (SS)} = \frac{E}{D} \text{ Persons}$$

$$= \frac{1133.12}{29.3} = 38.67 \text{ Persons}$$

$$\text{Productivity} = \frac{KLOC}{E} = \frac{200}{1133.12} = 0.1765 \text{ KLOC/PM}$$

P = 176 LOC/PM

2. Intermediate Model: The basic Cocomo model considers that the effort is only a function of the number of lines of code and some constants calculated according to the various software systems. The intermediate COCOMO model recognizes these facts and refines the initial estimates obtained through the basic COCOMO model by using a set of 15 cost drivers based on various attributes of software engineering.

Classification of Cost Drivers and their attributes:

(i) Product attributes -

- Required software reliability extent
- Size of the application database
- The complexity of the product

Hardware attributes -

- Run-time performance constraints
- Memory constraints
- The volatility of the virtual machine environment
- Required turnabout time

Personnel attributes -

- Analyst capability
- Software engineering capability
- Applications experience
- Virtual machine experience
- Programming language experience

Project attributes -

- Use of software tools
- Application of software engineering methods
- Required development schedule

The cost drivers are divided into four categories:

Cost Drivers	RATINGS					
	Very low	Low	Nominal	High	Very High	Extra High
Product Attributes						
RELY	0.75	0.88	1.00	1.15	1.40	..
DATA	..	0.94	1.00	1.08	1.16	..
CPLX	0.70	0.85	1.00	1.15	1.30	1.65
Computer Attributes						
TIME	..	..	1.00	1.11	1.30	1.66
STOR	..	..	1.00	1.06	1.21	1.56
VIRT	..	0.87	1.00	1.15	1.30	..
TURN	..	0.87	1.00	1.07	1.15	..

Cost Drivers	RATINGS					
	Very low	Low	Nominal	High	Very high	Extra high
Personnel Attributes						
ACAP	1.46	1.19	1.00	0.86	0.71	..
AEXP	1.29	1.13	1.00	0.91	0.82	..
PCAP	1.42	1.17	1.00	0.86	0.70	..
VEXP	1.21	1.10	1.00	0.90	..	..
LEXP	1.14	1.07	1.00	0.95	..	..
Project Attributes						
MODP	1.24	1.10	1.00	0.91	0.82	..
TOOL	1.24	1.10	1.00	0.91	0.83	..
SCED	1.23	1.08	1.00	1.04	1.10	..

COST DRIVER DESCRIPTION
RELY Required software reliability
DATA Database size
CPLX Product complexity
TIME Execution time constraints
STOR Main storage constraints
VIRT Virtual machine volatility - degree to which the operating system changes
TURN Computer turn around time
ACAP Analyst capability
AEXP Application experience
PCAP Programmer capability
VEXP Virtual machine (i.e. operating system) experience
LEXP Programming language experience
MODP Use of modern programming practices
TOOL Use of software tools
SCED Required development schedule

Intermediate COCOMO equation:

$$E=a_i (KLOC)b_i*EAF$$
$$D=c_i (E)d_i$$

Coefficients for intermediate COCOMO

Project	a_i	b_i	c_i	d_i
Organic	2.4	1.05	2.5	0.38
Semidetached	3.0	1.12	2.5	0.35
Embedded	3.6	1.20	2.5	0.32