SOFTWARE ENGINEERING

LECTURE:
COCOMO MODEL

Introduction to COCOMO models

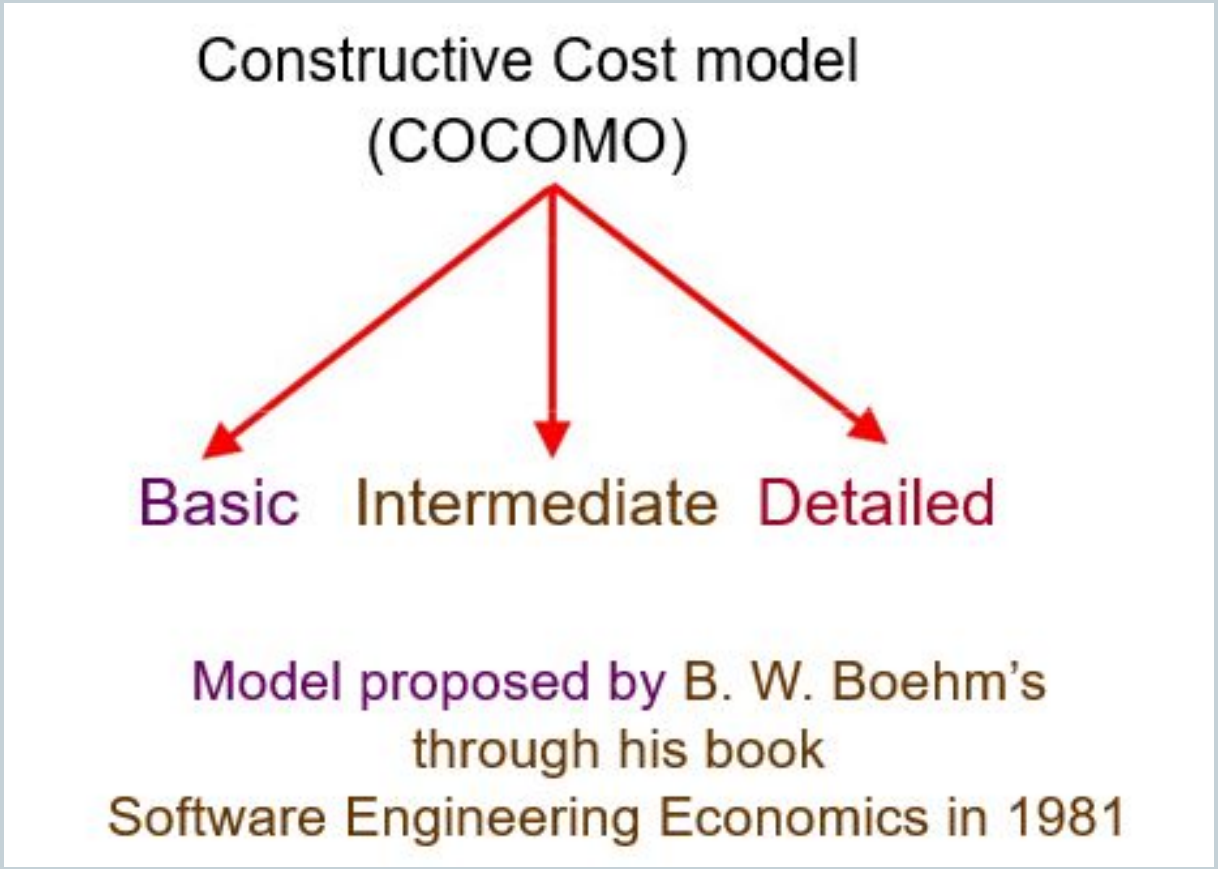
- The COnstructive COst MOdel (COCOMO) is the most widely used software estimation model in the world developed by Barry Boehm in 1970.

- It is a procedural cost estimate model for software projects and often used as a process of reliably predicting the various parameters associated with making a project such as size, effort, cost, time and quality.

Cont..

- The COCOMO model predicts the **effort** and **duration** of a project based on inputs relating to the size of the resulting systems and a number of "**cost drives**" that affect productivity.

The Constructive Cost Model (COCOMO)



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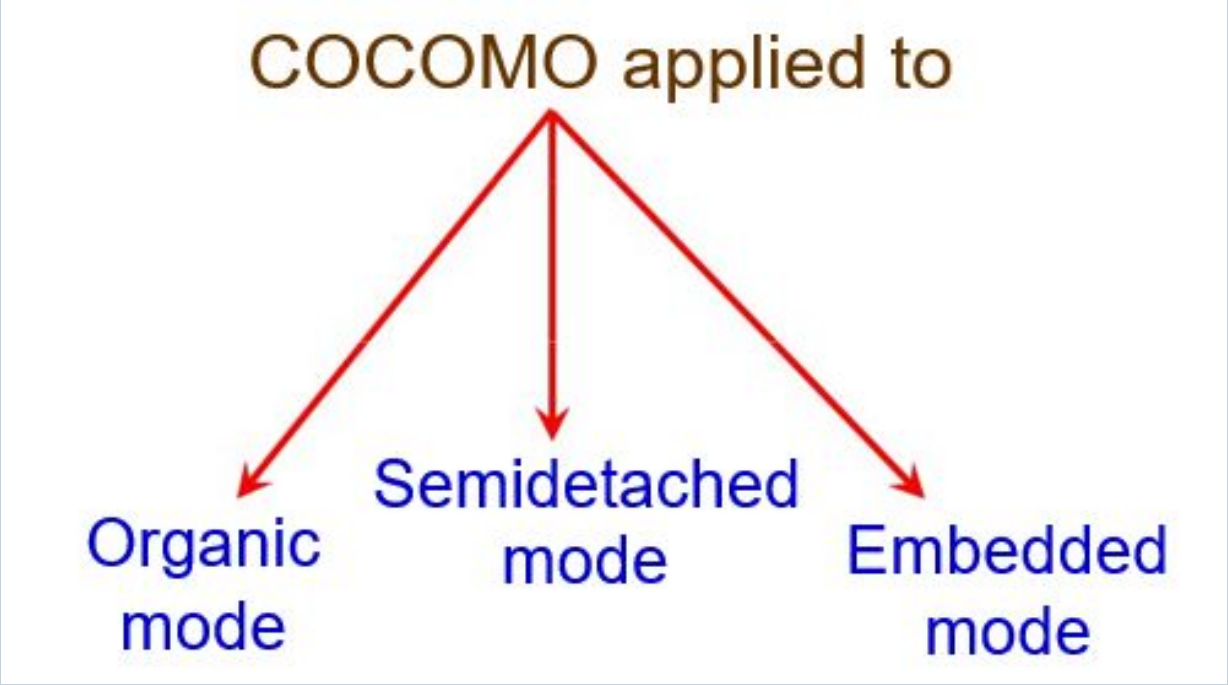

COCOMO

- In order to classify a project into the identified categories, Boehm requires us to consider not only the characteristics of the product but also those of the development team and development environment.
- Normally, data processing programs are considered to be application programs.
- Compilers, linkers, etc., are utility programs.
- Operating systems and real-time system programs, etc. are system programs. System programs interact directly with the hardware and programming complexities also arise out of the requirement for meeting timing constraints and concurrent processing of tasks.
- Brooks [1975] states that utility programs are roughly three times as difficult to write as application programs and system programs are roughly three times as difficult as utility programs.

COCOMO

Boehm's [1981] definitions of organic, semidetached, and embedded software are elaborated as follows:

- **Organic:** We can classify a development project to be of 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 types of projects.
- **Semidetached:** A development project can be classified to be of semidetached type, if the development team consists of a mixture of experienced and inexperienced staff. Team members may have limited experience on related systems but may be unfamiliar with some aspects of the system being developed.

COCOMO

- **Embedded:** A development project is considered to be of embedded type, if the software being developed is strongly coupled to hardware, or if stringent regulations on the operational procedures exist. Team members may have limited experience on related systems but may be unfamiliar with some aspects of the system being developed.

- For the three product categories, Boehm provides different sets of expressions to predict the effort (in units of person-months) and development time from the size estimation given in kilo lines of source code.

The comparison of three COCOMO modes

Mode	Project size	Nature of Project	Innovation	Deadline of the project	Development Environment
Organic	Typically 2-50 KLOC	Small size project, experienced developers in the familiar environment. For example, pay roll, inventory projects etc.	Little	Not tight	Familiar & In house
Semi detached	Typically 50-300 KLOC	Medium size project, Medium size team, Average previous experience on similar project. For example: Utility systems like compilers, database systems, editors etc.	Medium	Medium	Medium
Embedded	Typically over 300 KLOC	Large project, Real time systems, Complex interfaces, Very little previous experience. For example: ATMs, Air Traffic Control etc.	Significant	Tight	Complex Hardware/ customer Interfaces required

Basic COCOMO Model

The basic COCOMO estimation model is given by expressions of the following forms:

Effort = a1 × (KLOC) ^{a2} PM

D = b1 × (Effort) ^{b2} months

where,

KLOC is the estimated size of the software product expressed in Kilo Lines Of Code.

a1, a2, b1, b2 are constants for each category of software product.

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

Basic COCOMO Model

Software Project	a1	a2	b1	b2
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

Basic COCOMO coefficients

- When effort and development time are known, the average staff size to complete the project may be calculated as:

$$\text{Average staff size}(SS) = \frac{E}{D} \; Persons$$

- When project size is known, the productivity level may be calculated as:

$$\text{Productivity}(P) = \frac{KLOC}{E} \; KLOC/PM$$

Example

Suppose that a project was estimated to be 400 KLOC. Calculate the effort and development time for each of the three modes i.e., organic, semidetached and embedded.

Solution

- The basic COCOMO equation take the form:

$$E = a\,(KLOC)^{b}$$

$$D = c\,(KLOC)^{d}$$

- Estimated size of the project = 400 KLOC

(i) Organic mode

$$E = 2.4(400)^{1.05} = 1295.31 \text{ PM}$$

$$D = 2.5(1295.31)^{0.38} = 38.07 \text{ PM}$$

Solution

(ii) Semidetached mode

$$E = 3.0(400)^{1.12} = 2462.79 \text{ PM}$$

$$D = 2.5(2462.79)^{0.35} = 38.45 \text{ PM}$$

(iii) Embedded mode

$$E = 3.6(400)^{1.20} = 4772.81 \text{ PM}$$

$$D = 2.5(4772.8)^{0.32} = 38 \text{ PM}$$

Example

- 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 semi-detached mode is the most appropriate mode; keeping in view the size, schedule and experience of the development team.
- Hence

$$E = 3.0(200)^{1.12} = 1133.12 \text{ PM}$$

$$D = 2.5(1133.12)^{0.35} = 29.3 \text{ PM}$$

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

$$\text{size} = \frac{1133.12}{293} = 38.67 Persons$$

Solution

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

$$P = 176 \quad LOC/PM$$

Exercise

- Assume that the size of an organic type software product has been estimated to be 32,000 lines of source code. Assume that the average salary of a software developer is Rs. 15,000 per month. Determine the effort required to develop the software product, the nominal development time, and the cost to develop the product.

Solution

- From the basic COCOMO estimation formula for organic software:
- Effort = $2.4 \times (32)^{1.05} = 91$ PM
- Nominal development time = $2.5 \times (91)^{0.38} = 14$ months
- Staff cost required to develop the product = 91 × Rs. 15, 000 = Rs. 1,465,000

Basic COCOMO Model

- Basic COCOMO is good for quick, early, rough order of magnitude estimates of software costs, but it does not account for differences in hardware constraints, personnel quality and experience, use of modern tools and techniques and other project attributes known to have a significant influence on software costs, which limits its accuracy.

Intermediate Model

- Intermediate COCOMO computes software development effort as function of program size and a set of “cost drivers” that include subjective assessment of product, hardware, personnel and project attributes. This extension considers a set of four “cost drivers”, each with a number of subsidiary attributes.

Intermediate Model

Cost drivers

(*i*) Product Attributes

- Required s/w reliability (RELY)
- Size of application database (DATA)
- Complexity of the product (CPLX)

(*ii*) Hardware Attributes

- Run time performance constraints (TIME)
- Memory constraints (STOR)
- Virtual machine volatility (VIRT)
- Turnaround time (TURN)

Intermediate Model

(*iii*) Personal Attributes

- Analyst capability (ACAP)
- Application experience (AEXP)
- Programmer capability (PCAP)
- Virtual m/c experience (VEXP)
- Programming language experience (LEXP)

(*iv*) Project Attributes

- Modern programming practices (MODP)
- Use of software tools (TOOL)
- Required development Schedule (SCED)

Intermediate Model

Each of the 15 attributes receives a rating on a six-point scale that ranges from “very low” to “extra high” (in importance or value). An effort multiplier from the table given applies to the rating. The product of all effort multipliers results in an **effort adjustment factor (EAF)**. Typical values for EAF range from 0.9 to 1.4.

Multipliers of different cost drivers

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	--

Multipliers of different cost drivers

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	--

Intermediate COCOMO equations

$$E=a_i(KLoC)^{(b)}_i.EAF$$

$$D= c_i(E)^{d_i}$$

Project	a_i	b_i	c_i	d_i
Organic	3.2	1.05	2.5	0.38
Semidetached	3.0	1.12	2.5	0.35
Embedded	2.8	1.20	2.5	0.32

Coefficients for intermediate COCOMO

Example

A new project with estimated 400 KLOC embedded system has to be developed. Project manager has a choice of hiring from two pools of developers: Very highly capable with very little experience in the programming language being used

OR

Developers of low capability but a lot of experience with the programming language. What is the impact of hiring all developers from one or the other pool ?

Solution

This is the case of embedded mode and model is intermediate COCOMO.

Hence $E=a_i(KLoC)^{(b)}_i.EAF$

$= 2.8(400)^{1.20} = 3712$ PM

Case I: Developers are very highly capable with very little experience in the programming being used.

EAF = 0.70 x 1.14 = 0.798

E = 3712 x .798 = 2962 PM

D = $2.5\ (3470)^{0.32}$ = 33.9 M

Solution

Case II: Developers are of low capability but lot of experience with the programming language being used.

EAF = 1.17 x 0.95 = 1.11

E = 3712 x 1.11 = 4125 PM

D = $2.5 (4528)^{0.32}$ = 36.9 M

Case II requires more effort and time. Hence, low quality developers with lot of programming language experience could not match with the performance of very highly capable developers with very little experience.

Exercise

For the following project description, generate estimates for total effort, project duration, and number of people needed using the intermediate COCOMO model.

CADCO, Inc., wants to produce a system that will perform computer-aided design for the home construction industry. They are a new company, and though they want to be the best in CAD systems, they are still, overall, a bit inexperienced. This project, then, for CADCO (at this time in their history) would be considered ◦ **WHAT TYPE?**

Initial analysis of the problem leads to requirements calling for 3 major modules, with the following sizes:

screen drawing	2.00 KDSI
object-base management	3.50 KDSI
algebra/numerical methods	1.75 KDSI

The programmers that CADCO hired to start are among the best in the business, but most have never used C++ before, which will be the language of implementation. The system must run fairly fast, since users will be impatient if drawing takes too long. CADCO also would like to make their market as large as possible, which means the package should run on slower PCs as well as faster ones. Many models will accumulate over time; the house simulation routines and solid modeling routines will require a great deal of memory to operate efficiently. For the project, then, these effort adjustment factors are estimated:

data base size	high
product complexity	very high
main storage	very high
execution time constraints	high
programmer capability	very high
programming language experience	very low

all other characteristics rated nominal

Solution

What Project Type? SEMI-DETACHED

screen drawing	2.00 KDSI
object-base management	3.50 KDSI
algebra/numerical methods	1.75 KDSI
total SIZE	7.25 KDSI

Effort $PM = EAF * 3.0 * (SIZE)^{1.12}$

> 40 person-months

$PM = (1.05*1.30*1.21*1.11*0.70*1.14) * 3.0 * (7.25)^{1.12}$
$PM = 1.46 * 3.0 * 9.19$
$PM = 40.25$

Project Duration $D = 2.5 * (PM)^{0.35}$

> 9 calendar months

$D = 2.5 * (40.25)^{0.35}$
$D = 2.5 * 3.64$
$D = 9.10$

Staffing $P = PM/D$

4 or 5 people needed

$P = 40.25 / 9.10$
$P = 4.42$

COCOMO II (Detailed)

- Detailed COCOMO- incorporates all characteristics of the intermediate version with an assessment of the cost driver's impact on each step (analysis, design etc.) of the software engineering process.