

COCOMO : Constructive Cost Model

* Developed by Barry Bob Boehm

* It is hierarchy of software cost

* It is cost estimation model

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

- (1) Basic COCOMO
- (2) Intermediate COCOMO
- (3) Complete COCOMO

1. Basic COCOMO Model

- * It estimates software in rough & quick manner
- * Mostly used for small-size software
- * It has small size team
- * Experience developer needed
- * Deadlines are not strict

$$1. \text{ Effort} \rightarrow a (\text{KLOC})^b$$

$$2. \text{ Development time} \rightarrow c (\text{Effort})^d \text{ months}$$

$$3. \text{ Average Staff} \rightarrow \frac{\text{Effort}}{\text{Development Time}} \text{ Person}$$

$$4. \text{ Productivity} \rightarrow \frac{\text{KLOC}}{\text{Effort}} \text{ KLOC/P.M}$$

Question: Suppose that a project was estimated to be 400 KLOC. Calculate effort & time for each of three modes of development.

1- Organic

$$\text{Effort} = a (KLOC)^b \text{ person-month}$$

$$= 2.4 (400)^{1.05}$$

$$= 1295 \text{ PM}$$

$$\text{Development Time} = \cancel{c} \cdot \cancel{C} (\text{Effort})^d \text{ mon}$$

$$= 2.5 \cdot (1295)^{0.38}$$

$$= 38 \text{ Month.}$$

2- Semidetached

$$\text{Effort} = 3 \times (400)^{1.12} = 2462 \text{ PM}$$

$$\text{Development time} = 2.5 \times (2462)^{0.35}$$

$$= 38.4 \text{ months}$$

3- Embedded

$$\text{Effort} = 3.6 \times (400)^{1.2} = 4772 \text{ PM}$$

$$\text{Development Time} = 2.5 \times (4772)^{0.32}$$

$$= 38 \text{ Months}$$

	<u>Organic</u>	<u>Semi Deakthed</u>	<u>Embedded</u>
Size	2-50 KLOC	50-300 KLOC	300-8 KLOC
Team Size	Small size	Medium size	Large size
Developer Experience	Developer experience	Average Experience per developer	Very little previous experience
Environment	Familiar Environment	Less familiar	Significant environment changes (Almost new environment)
Innovation	Little	Medium	Major
Deadline	Not tight	Medium	Tight
	Parallel System	Utility System Compiler	Air traffic monitoring

Mode	a	b	c	d
Organic	2.4	1.05	2.5	0.38
Semi-deakthed	3.0	1.12	2.5	0.35
Embedded	3.6	1.20	2.5	0.32

Cocomo has three modes of development

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graph TD
    Top(( )) --- Organic[Organic]
    Top --- Semi[Semi-deakthed]
    Top --- Embedded[Embedded]
  
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Intermediate Model

For A new project with estimated 400 KLOC embedded system has to be developed. Project manager has a choice of hiring from 2 pools of developers:

- Very high capable (with app1) with very little experience in programming language OR
- Developers of low quality but a lot of programming language experience which is better experience in terms of 2 pools.

$$E = a (KLOC)^b \times EAF$$

$$E = 2.8 \times (400)^{1.20} \times EAF$$

$$\begin{aligned} \text{Case I} &= EAF = 0.82 \times 1.14 \\ &= 0.934 \end{aligned}$$

$$E = 2.8 (400)^{1.20} \times 0.934$$

$$\boxed{E = 3470 \text{ PMPM}}$$

Development Time

$$D = 2.5 (3470)^{0.32}$$

$$\boxed{= 33.9 \text{ months}}$$

Case II

$$EAF = 1.29 \times 0.95$$

$$= 1.22$$

$$E = 2.8 (400)^{1.20} \times 1.22$$

$$= 3412 \times 1.22$$

$$\boxed{E = 4528 \text{ PPM}}$$

$$D \cdot T = 2.5 (4528)^{0.32}$$

$$\boxed{D \cdot T = 36.9 \text{ M}}$$

COCOMO: The Intermediate Model

Difference Between Basic & Intermediate model:

1. Basic Model / was quick but inaccurate & phase ~~inset~~ insertion
2. Intermediate model includes a set of 15 additional predictions (cost Drivers)
3. It also take development environment into account during cost estimation.

Use of Cost Driver

Cost driver adjust nominal cost of project to actual project environment
↳ increasing accuracy of estimation

15 Cost Driver

I Product Attributes

- a) Required SW Reliability (CREL)
- b) Database Size (DATA)
- c) Product Complexity (CPLX)

II Computer Attributes

- a) Execution time constraint (TIME)
- b) Main storage constraint (STOR)
- c) Virtual Machine Volatility (VIRT)
- d) Computer Turnaround time (TURN)

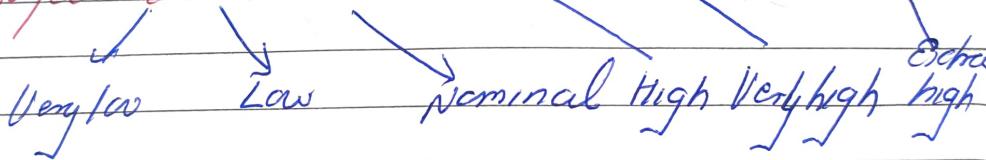
III Personal Attributes

- a) Analyst Capability
- b) Application Experience
- c) Programme Capability
- d) Virtual Machine Experience
- e) Programming language Experience

IV Project Attributes

- (a) Modern Programming Practices
- (b) Use of S/w tools
- (c) Required development schedule

Each Cost Driver is coded from the given project environment



Effort Adjustment factor (EAF)

Calculated by multiplying all the values that have been obtained after categorizing each cost driver.

Equation for COCOMO

$$\text{Effort} = q_i (k\text{LOC})^{b_i} \times \text{EAF}$$

$$\text{Development Time} = c_j (\text{Effort})^{\alpha_j}$$

Table 5.1: Multipliers of different cost drivers

Cost Drivers	Ratings					
	Very low	Low	Nominal	High	Very	Extra
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	-
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	-

The multiplying factors for all 15 cost drivers are multiplied to get the effort adjustment factor (EAF). Typically values for EAF ranges from 0.9 to 1.4.

The intermediate COCOMO equations take the form:

$$E = a_i(KLOC)^{b_i} \times EAF$$

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

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$$E = a_i(\text{KLOC})^{b_i} \times \text{EAF}$$

Mode	q_1	b_1	c_1	d_1
Organic	3.2	1.05	2.5	0.38
Semi Detached	3.0	1.12	2.5	0.38
Embedded	2.8	1.20	2.5	0.32

COCOMO : Detailed Development Model

- * It calculates the effort Cost Driver on each phase of SDLC
- * It uses phase specific effort multipliers for each cost driver to determine the amount of effort required to complete each phase of SDLC.
- * It establishes Module subsystem Hierarchy
- The rating of cost driver is done at the level only where cost driver is most susceptible to variable.
- * Adjustment factor (A)

$$A = 0.4(DD) + 0.3C + 0.3T$$

DD is Design Documentation
C is Code
T is Integration Testing / Testing

* Size-Equivalent Equivalent

$$\left[\frac{(S \times A)}{100} \right]$$

For Intermediate COCOMO Model

Mode	q_i	b_i	c_i	d_i
Organic	3.2	1.05	2.5	0.38
Semi-Detached	3.0	1.12	2.5	0.38
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~~X~~~~X~~~~X~~

Y

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DD is Design Documentation

C is Code

I Integration Testing / Testing

- * Size ~~Equation~~ Equivalent

$$\left[\frac{(S \times A)}{100} \right]$$

<u>Mode and CodeSize</u>	<u>Plan & Req</u>	<u>System Design</u>	<u>Detail Design</u>	<u>Code Test</u>	<u>Intg. Test</u>
<u>Life Cycle Phase</u>	<u>Value</u>	<u>Up</u>			
Organic Small $S=2$	0.06	0.16	0.26	0.42	0.8
Organic Medium $S \approx 32$	0.06	0.16	0.24	0.38	0.4
Semi-det Medium $S \approx 32$	0.7	0.17	0.25	0.33	0.25
Sem-det Large $S \approx 128$	0.7	0.17	0.24	0.31	0.28
Embed Large $S \approx 128$	0.08	0.18	0.25	0.36	0.31
Embeded XL $S \approx 320$	0.08	0.18	0.24	0.24	0.31

Life Cycle Phase value of Up

Organic Small $S=2$	•16	•19	•24	•39	•18
Organic Medium $S \approx 32$	•12	•19	•21	•34	•26
S-Det Med $S \approx 32$	•20	•26	•21	•27	•26
S-Det Large $S \approx 128$	•22	•27	•19	•25	•29
Emb Large $S \approx 128$	•36	•36	•18	•18	•28
Emb XL $S \approx 320$	•40	•38	•16	•16	•30

$$\text{Effort} = Up E$$

$$\text{Development Time} = Up D$$

(Octalite cocomo model)

Question Consider the project with following main component (1) Screen Edit (2) CLI (3) file I/P and o/p (4) cursor move (5) screen movement. The size of these are estimated to be 4K, 2K, 1K, 3K LOC. Using COCOMO determine

- I Overall cost & Schedule estimate
(assume value of K cost drivers with at least 3 being different from 1.0)
- II Cost & schedule estimates for different phases.

$$\text{I Effort} = q_i \cdot (K \text{LOC})^{b_i} \times EAF$$

$$q_i = 3.2 \quad b_i = 1.05 \quad K = 12 \quad EAF = 1.15$$

S/w Reliability: High
Long Experience: Low
Product Complexity: High
Analyst Capability: High

$$EAF = 1.15 \times 1.15 \times 0.86 \times 1.07 \\ = 1.216$$

$$\text{Effort} = q_i \cdot (K \text{LOC})^{b_i} \times EAF \\ = 3.2 (12)^{1.05} \times 1.216 \\ = 52.9 \text{ P.M}$$

Development Time

$$C_i (E) d_i \\ 2 - 5 (52.9)^{0.38} \\ = 11.29 \text{ months}$$

$$\text{II} \quad \text{Effort} = M_p \times E$$

$$\text{Development Time} = T_p D$$

Effort

Plan & Requirement	=	0.06×52.9	Person Month
Design	=	0.16×52.9	
Detail Design	=	0.26×52.9	
Code & Test	=	0.42×52.9	
Integration & Test	=	0.16×52.9	

Development Time

Plan & Request	=	0.10×11.29	Months
Design	=	0.19×11.29	
Detail Design	=	0.24×11.29	
Code & Test	=	0.39×11.29	
Integration & Test	=	0.16×11.29	