COCOMO Model

Lecture – 10

Outline of the talk

- **COCOMO Model**
- **Types of COCOMO Model**
- **COCOMO – II**

The Constructive Cost Model (COCOMO)

Constructive Cost model
(COCOMO)

Basic Intermediate Detailed

Model proposed by
B. W. Boehm's
through his book
Software Engineering Economics in 1981

Software Project Planning

COCOMO applied to

- Organic mode
- Semidetached mode
- Embedded mode

Software Project Planning

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

Table 4: The comparison of three COCOMO modes

Software Project Planning

Basic Model

Basic COCOMO model takes the form

$$E = a_b (KLOC)^{b_b}$$

$$D = c_b (E)^{d_b}$$

where E is effort applied in Person-Months, and D is the development time in months. The coefficients a_b, b_b, c_b and d_b are given in table 4 (a).

Software Project Planning

Software Project	a_b	b_b	c_b	d_b
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

Table 4(a): Basic COCOMO coefficients

Software Project Planning

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

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

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

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

Example: 4.5

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:

$$E = a_b (KLOC)^{b_b}$$

$$D = c_b (KLOC)^{d_b}$$

Estimated size of the project = 400 KLOC

(i) Organic mode

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

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

Software Project Planning

(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

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

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

Software Project Planning

Example: 4.6

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.

Software Project Planning

Solution

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

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

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

Average staff size $(SS) = \dfrac{E}{D}\ Persons$

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

Software Project Planning

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

$$P = 176\ LOC/PM$$

Software Project Planning

Intermediate Model

Cost drivers

(*i*) Product Attributes

- Required s/w reliability
- Size of application database
- Complexity of the product

(*ii*) Hardware Attributes

- Run time performance constraints
- Memory constraints
- Virtual machine volatility
- Turnaround time

Software Project Planning

(*iii*) Personal Attributes

- Analyst capability
- Programmer capability
- Application experience
- Virtual m/c experience
- Programming language experience

(*iv*) Project Attributes

- Modern programming practices
- Use of software tools
- Required development Schedule

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	--

Software Project Planning

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	--

Table 5: Multiplier values for effort calculations

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

Table 6: Coefficients for intermediate COCOMO

Software Project Planning

Detailed COCOMO Model

Detailed COCOMO

Phase-Sensitive effort multipliers

Three level product hierarchy

Cost drivers

design & test

Modules

subsystem

System level

Manpower allocation for each phase

Software Project Planning

<u>Development Phase</u>

Plan / Requirements

EFFORT	:	6% to 8%
DEVELOPMENT TIME	:	10% to 40%

% depend on mode & size

Software Project Planning

Design

Effort	:	16% to 18%
Time	:	19% to 38%

Programming

Effort	:	48% to 68%
Time	:	24% to 64%

Integration & Test

Effort	:	16% to 34%
Time	:	18% to 34%

Principle of the effort estimate

Size equivalent

As the software might be partly developed from software already existing (that is, re-usable code), a full development is not always required. In such cases, the parts of design document (DD%), code (C%) and integration (I%) to be modified are estimated. Then, an adjustment factor, A, is calculated by means of the following equation.

A = 0.4 DD + 0.3 C + 0.3 I

The size equivalent is obtained by

S (equivalent) = (S x A) / 100

$$E_p = \mu_p E$$

$$D_p = \tau_p D$$

Software Project Planning

Lifecycle Phase Values of μ_p

Mode & Code Size	Plan & Requirements	System Design	Detailed Design	Module Code & Test	Integration & Test
Organic Small S≈2	0.06	0.16	0.26	0.42	0.16
Organic medium S≈32	0.06	0.16	0.24	0.38	0.22
Semidetached medium S≈32	0.07	0.17	0.25	0.33	0.25
Semidetached large S≈128	0.07	0.17	0.24	0.31	0.28
Embedded large S≈128	0.08	0.18	0.25	0.26	0.31
Embedded extra large S≈320	0.08	0.18	0.24	0.24	0.34

Table 7 : Effort and schedule fractions occurring in each phase of the lifecycle

Software Project Planning

Lifecycle Phase Values of τ_p

Mode & Code Size	Plan & Requirements	System Design	Detailed Design	Module Code & Test	Integration & Test
Organic Small S≈2	0.10	0.19	0.24	0.39	0.18
Organic medium S≈32	0.12	0.19	0.21	0.34	0.26
Semidetached medium S≈32	0.20	0.26	0.21	0.27	0.26
Semidetached large S≈128	0.22	0.27	0.19	0.25	0.29
Embedded large S≈128	0.36	0.36	0.18	0.18	0.28
Embedded extra large S≈320	0.40	0.38	0.16	0.16	0.30

Table 7 : Effort and schedule fractions occurring in each phase of the lifecycle

Software Project Planning

Distribution of software life cycle:

1. Requirement and product design
   (a) Plans and requirements
   (b)System design

2. Detailed Design
   (a) Detailed design

3. Code & Unit test
   (a) Module code & test

4. Integrate and Test
   (a) Integrate & Test

Software Project Planning

Example: 4.7

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 quality 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 $$E = a_i (KLOC)^{d_i}$$

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

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

EAF = 0.82 x 1.14 = 0.9348

E = 3712 x .9348 = 3470 PM

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

Software Project Planning

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

$$EAF = 1.29 \times 0.95 = 1.22$$

$$E = 3712 \times 1.22 = 4528 \text{ PM}$$

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

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 litter experience.

Example: 4.8

Consider a project to develop a full screen editor. The major components identified are:

I. Screen edit

II. Command Language Interpreter

III. File Input & Output

IV. Cursor Movement

V. Screen Movement

The size of these are estimated to be 4k, 2k, 1k, 2k and 3k delivered source code lines. Use COCOMO to determine

1. Overall cost and schedule estimates (assume values for different cost drivers, with at least three of them being different from 1.0)

2. Cost & Schedule estimates for different phases.

Solution

Size of five modules are:

Screen edit	= 4 KLOC
Command language interpreter	= 2 KLOC
File input and output	= 1 KLOC
Cursor movement	= 2 KLOC
Screen movement	= 3 KLOC
Total	**= 12 KLOC**

Software Project Planning

Let us assume that significant cost drivers are

i. Required software reliability is high, i.e.,1.15

ii. Product complexity is high, i.e.,1.15

iii. Analyst capability is high, i.e.,0.86

iv. Programming language experience is low,i.e.,1.07

v. All other drivers are nominal

$$EAF = 1.15 \times 1.15 \times 0.86 \times 1.07 = 1.2169$$

Software Project Planning

(a) The initial effort estimate for the project is obtained from the following equation

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

$$= 3.2(12)^{1.05} \times 1.2169 = 52.91\ PM$$

Development time $D = C_i(E)^{d_i}$

$$= 2.5(52.91)^{0.38} = 11.29\ M$$

(b) Using the following equations and referring Table 7, phase wise cost and schedule estimates can be calculated.

$$E_p = \mu_p E$$

$$D_p = \tau_p D$$

Software Project Planning

Since size is only 12 KLOC, it is an organic small model. Phase wise effort distribution is given below:

System Design	= 0.16 x 52.91 = 8.465 PM
Detailed Design	= 0.26 x 52.91 = 13.756 PM
Module Code & Test	= 0.42 x 52.91 = 22.222 PM
Integration & Test	= 0.16 x 52.91 = 8.465 Pm

Now Phase wise development time duration is

System Design	= 0.19 x 11.29 = 2.145 M
Detailed Design	= 0.24 x 11.29 = 2.709 M
Module Code & Test	= 0.39 x 11.29 = 4.403 M
Integration & Test	= 0.18 x 11.29 = 2.032 M

COCOMO-II

The following categories of applications / projects are identified by COCOMO-II and are shown in fig. 4 shown below:

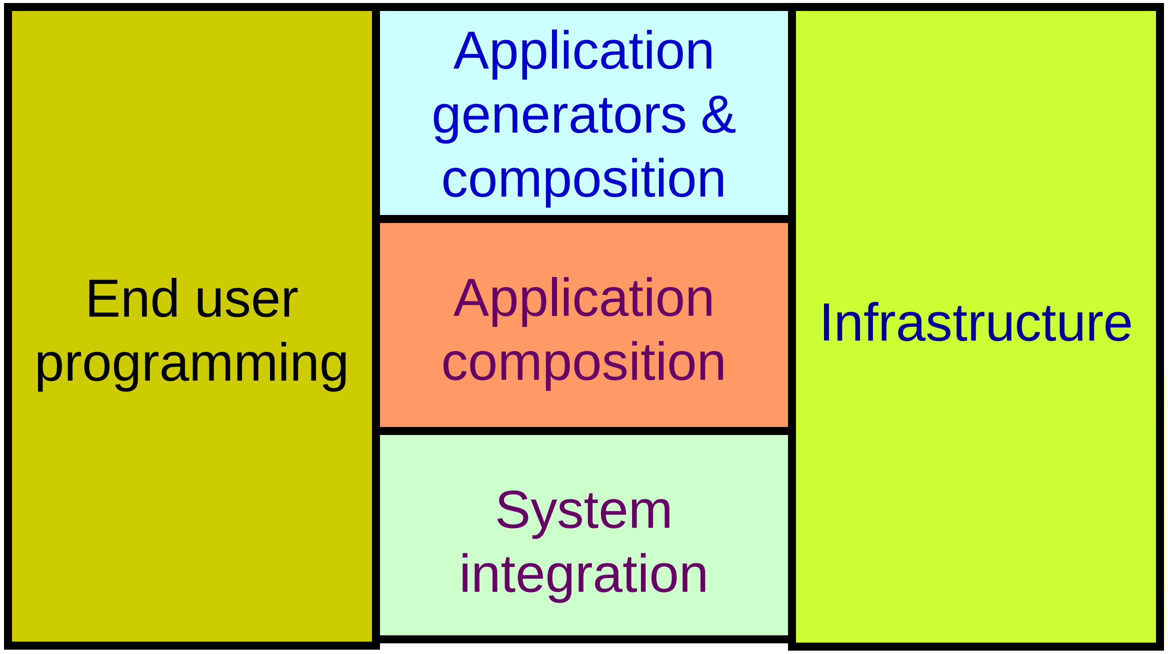

Fig. 4 : Categories of applications / projects

Software Project Planning

Stage No	Model Name	Application for the types of projects	Applications
Stage I	Application composition estimation model	Application composition	In addition to application composition type of projects, this model is also used for prototyping (if any) stage of application generators, infrastructure & system integration.
Stage II	Early design estimation model	Application generators, infrastructure & system integration	Used in early design stage of a project, when less is known about the project.
Stage III	Post architecture estimation model	Application generators, infrastructure & system integration	Used after the completion of the detailed architecture of the project.

Table 8: Stages of COCOMO-II

Application Composition Estimation Model

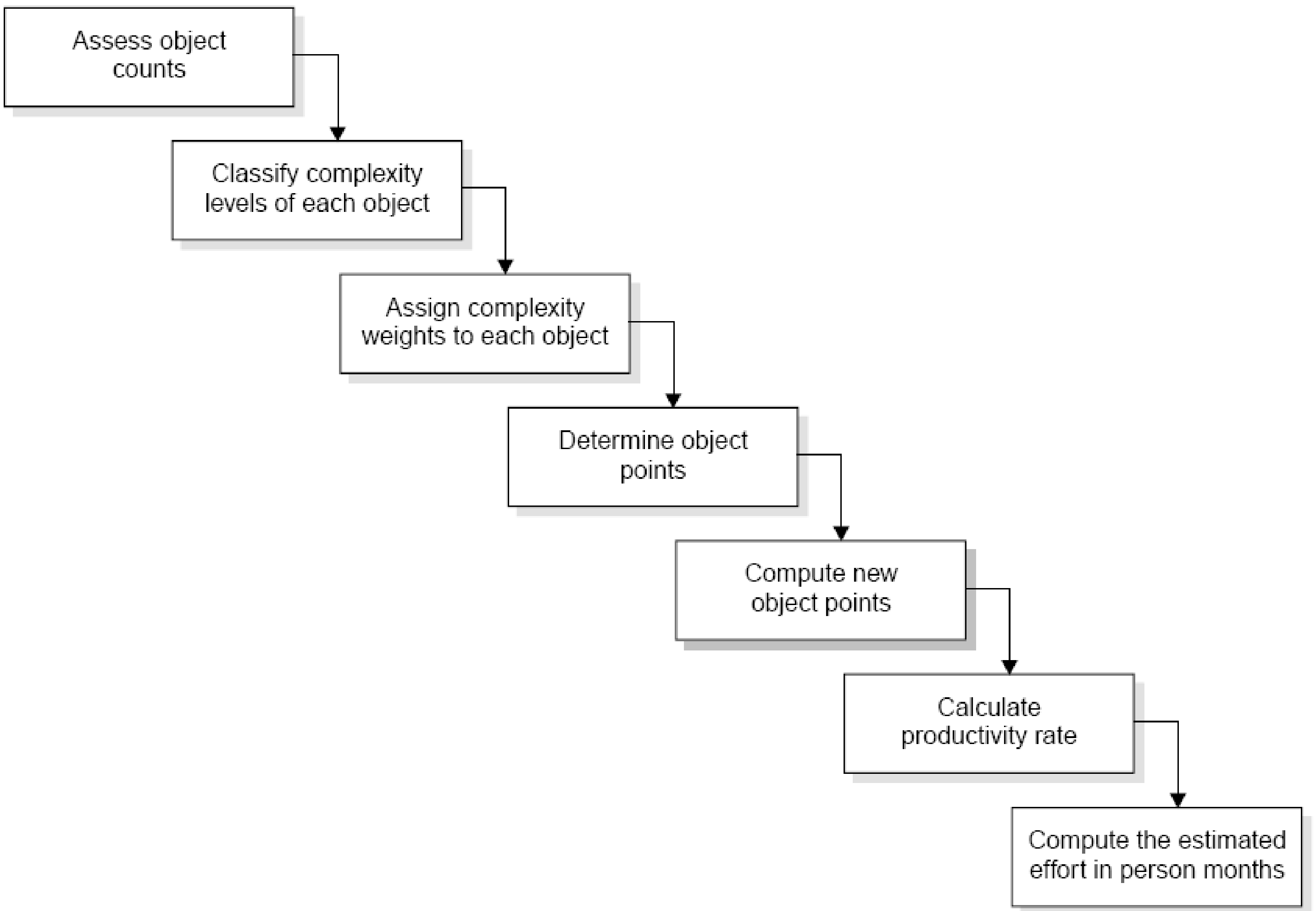

Fig.5: Steps for the estimation of effort in person months

Software Project Planning

i. Assess object counts: Estimate the number of screens, reports and 3 GL components that will comprise this application.

ii. Classification of complexity levels: We have to classify each object instance into simple, medium and difficult complexity levels depending on values of its characteristics.

Number of views contained	*# and sources of data tables*		
	Total < 4 (< 2 server < 3 client)	*Total < 8 (2 – 3 server 3 – 5 client)*	*Total 8 + (> 3 server, > 5 client)*
< 3	Simple	Simple	Medium
3 – 7	Simple	Medium	Difficult
> 8	Medium	Difficult	Difficult

Table 9 (a): For screens

Software Project Planning

Number of sections contained	# and sources of data tables		
	Total < 4 (< 2 server < 3 client)	Total < 8 (2 – 3 server 3 – 5 client)	Total 8 + (> 3 server, > 5 client)
0 or 1	Simple	Simple	Medium
2 or 3	Simple	Medium	Difficult
4 +	Medium	Difficult	Difficult

Table 9 (b): For reports

Software Project Planning

iii. Assign complexity weight to each object : The weights are used for three object types i.e., screen, report and 3GL components using the Table 10.

Object Type	*Complexity Weight*		
	Simple	*Medium*	*Difficult*
Screen	1	2	3
Report	2	5	8
3GL Component	—	—	10

Table 10: Complexity weights for each level

Software Project Planning

iv. Determine object points: Add all the weighted object instances to get one number and this known as object-point count.

v. Compute new object points: We have to estimate the percentage of reuse to be achieved in a project. Depending on the percentage reuse, the new object points (NOP) are computed.

$$\textbf{NOP} = \frac{(\text{object points}) * (100-\%\text{reuse})}{100}$$

NOP are the object points that will need to be developed and differ from the object point count because there may be reuse.

Software Project Planning

vi. Calculation of productivity rate: The productivity rate can be calculated as:

Productivity rate (PROD) = NOP/Person month

Developer's experience & capability; ICASE maturity & capability	*PROD (NOP/PM)*
Very low	4
Low	7
Nominal	13
High	25
Very high	50

Table 11: Productivity values

vii. Compute the effort in Persons-Months: When PROD is known, we may estimate effort in Person-Months as:

$$\textbf{Effort in PM} = \frac{NOP}{PROD}$$

Example: 4.9

Consider a database application project with the following characteristics:

I. The application has 4 screens with 4 views each and 7 data tables for 3 servers and 4 clients.

II. The application may generate two report of 6 sections each from 07 data tables for two server and 3 clients. There is 10% reuse of object points.

The developer's experience and capability in the similar environment is low. The maturity of organization in terms of capability is also low. Calculate the object point count, New object points and effort to develop such a project.

Solution

This project comes under the category of application composition estimation model.

Number of screens = 4 with 4 views each

Number of reports = 2 with 6 sections each

From Table 9 we know that each screen will be of medium complexity and each report will be difficult complexity.

Using Table 10 of complexity weights, we may calculate object point count.

$$= 4 \times 2 + 2 \times 8 = 24$$

$$\textbf{NOP} = \frac{24 * (100 - 10)}{100} = 21.6$$

Software Project Planning

Table 11 gives the low value of productivity (PROD) i.e. 7.

$$\text{Efforts in PM} = \frac{NOP}{PROD}$$

$$\text{Efforts} = \frac{21.6}{7} = 3.086 \text{ PM}$$

Assignment

- Explain COCOMO Model in detail

Research Work

- **Cost *Models* for Future Software Life Cycle Processes: *COCOMO* 2**