Project Effort and Cost Estimation.

A Guide.

1 COCOMO – A Cost Estimation Model.

COnstructive COst MOdeling.

Introduced by Barry Boehm.

This model has been developed, to understand the cost consequences of the decision made in commissioning, developing and supporting a software product.

Elements in COCOMO calculations.

Inputs

1. KDSI (Delivered Source Instructions) of deliverables.
2. Cost Drivers (taken from the system).

Outputs

1. MM (Effort)
2. Development Duration
3. Team size
4. Development cost

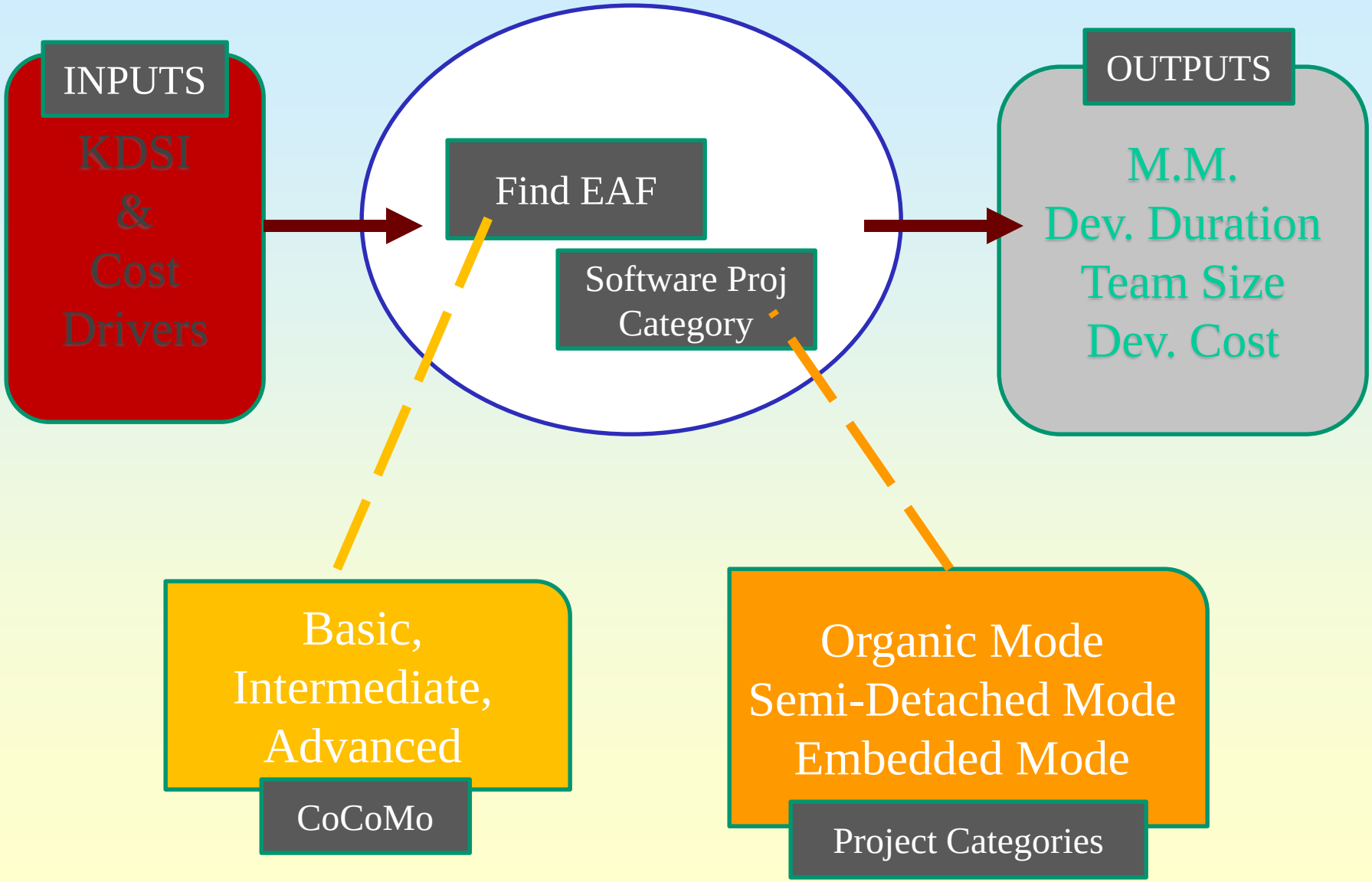
Models Referred

1. CoCoMo Models

   [Basic, Intermediate, Advanced]
2. Software Project Models

   [Organic, Semi-detached, Embedded]

Elements in COCOMO calculations.



1.1 Input for COCOMO models.

DSI – Delivered Source Instructions.

Lines of code actually delivered as end-product.

These include:

1. Data declarations.
2. Classes.
3. Libraries (single instances).

Excluding:

1. Undelivered support software (testing, debugging utilities etc.)
2. Comments.
3. Reused code components (other than libraries).

KDSI – Kilo Delivered Source Instructions.

i.e. 1 KDSI = 1000 DSI. (DSI a.k.a. LOC)

1.1 Input for COCOMO models.

Cost Drivers.

Subjective assessments taken from a few system attributes.

(a) Product Attributes

(b) Personnel Attributes

(c) Computer Attributes

(d) Project Attributes

These attributes yield a value known as EAF which is used as input in the equations of COCOMO.

Man Months and Man Months

Man Hours

The **amount of work** done in **one clock hour** by **one person**

[without breaks]

Remember: This is a unit of effort and not a unit of time.

MM – Man Months (The Effort).

Value varies from place to place.

Includes.

All activities from product design to unit testing.

Excludes.

Leaves, training period, installation planning, conversion, overheads, etc.

Concept of Man Months / Person Months

What does it mean?

The number of hours a man (person) can work in a month.

Usually a man day is 8 hours, therefore a **man week** is:

8 hours * 5 days a week = 40 hours

since there is usually 4 weeks in a month it is (man month):

40 hours * 4 = 160 hours.

a **man year** is 12 * 160 = 1920 hours.

The modern day name is Person Months.

1.2 Software Categories as per COCOMO.

These are actually the software development modes.

COCOMO models are defined for 3 classes of software projects.

Using Boehm's terminology these are:

1. **Organic Mode.**
2. **Semi-detached Mode.**
3. **Embedded Mode.**

1.2.1 Software Category: Organic Mode Projects.

Projects where:

- Relatively small teams are working efficiently.
- A familiar environment.
- Developing well-understood applications.

Mostly in-house routine projects.

For example:

- A data analysis application developed for a mechanical industry unit involving heat transfer.

1.2.2 Software Category: Semi-detached Mode Projects.

Projects with:

- Intermediate (medium sized teams).
- Consisting of both experienced and inexperienced members.
- Members may have:
  - Some or limited experience of similar systems
    - and
  - May be unfamiliar with some aspects of the current system.

Neither large nor small projects (medium).

For example:

- A transaction-processing system with fixed requirements for terminal hardware and database software.

1.2.3 Software Category: Embedded Mode Projects.

Projects:

Which are relatively large sized.

Where difficulties are expected.

These are concerned with developing software, which is part of strongly coupled complex of hardware, software and operational constraints.

Mostly defense related projects or similar.

The team members do not have much prior experience in the application being developed.

For example:

A flight control system for an aircraft or a nuclear plant software.

1.3 COCOMO Modeling Assumptions.

- DSI include non-comment lines of computer-processed code.
- Development life cycle starts at the beginning of product design.
- It ends with the acceptance test (concluding integration and test).
- Requirements analysis effort are estimated separately as an additional percentage of development estimate.
- Activities include only direct-charged project efforts.
- Excluding: typical project over-heads such as administrative support, facilities and equipment.
- A staff-month (effort) consists of 160 hours.

2 COCOMO Hierarchy Models.

COCOMO not only provides cost estimation it also provides capabilities for sensitivity analysis and trade-off analysis of many of the common software engineering decision issues.

As described by Barry Boehm; the COCOMO model is hierarchy of following three increasingly detailed models:

1. **Basic COCOMO model.**
2. **Intermediate COCOMO model.**
3. **Advanced COCOMO model.**

2.1 Basic COCOMO Model.

(a.k.a. Model 1).

This model computes software development effort as a function of program size.

Program size is expressed in DSI.

DSI – Delivered Source Instructions.

Almost same as lines of code.

$\mathbf{MM = a \times (KDSI)^{b}}$ [Man months or the effort]

$\mathbf{T_{dev} = c \times (MM)^{d}}$ [Calendar Time for development.]

Values of a, b, c and d can located from a table in coming slides.

2.2 Intermediate COCOMO Model.

(a.k.a. Model 2).

This model computes software development effort as a function of program size and a set of cost drivers that include subjective assessment of products, hardware, personnel and project attributes.

$$\mathbf{MM = a \times (KDSI)^{b} \times EAF}$$

$$\mathbf{T_{dev} = c \times (MM)^{d}}$$ (same as basic model)

Values of a, b, c and d can located from a table in coming slides.

2.2.0 Project Characteristics as Cost Drivers.

The cost drivers are subjective assessments of products, hardware, personnel and project attributes.

We shall discuss each of these categories.

Each of these attributes is rated on a scale with six possible values .

An EAF (effort adjustment factor) is calculated from the product of all attribute ratings from a Boehm published table.

The EAF is then placed in the COCOMO equations for the model 2 to calculate the project effort (MM).

2.2.1 Cost Drivers – Product Attributes.

1. RELY: Required software reliability.

   Dependable software? How much?

2. DATA: Size of database.

   How many records?

3. CPLX: Complexity of the product.

   Controls, mathematics, logic, etc.

2.2.2 Cost Drivers – Hardware Attributes.

1. TIME: Run-time performance constraints.
   How many resources?
2. STOR: Main-storage (memory) constraints.
   Needs what % of total memory.
3. VIRT: Volatility of the virtual-machine environment.
   Collection of hardware and OS tools.
4. TURN: Computer turn-around time.
   How fast?

2.2.3 Cost Drivers – Personnel (people) Attributes.

1. ACAP: Analyst capability.
2. PCAP: Software engineer (programmer) capability.
3. AEXP: Applications experience.
4. VEXP: Virtual machine experience.
5. LEXP: Programming language experience.

2.2.4 Cost Drivers – Project Attributes.

1. TOOL: Use of software tools.

   Modern building tools.

2. MODP: Use of modern software engineering methods.

   Modern modeling and designing tools and methods.

3. SCED: Required development schedule.

   Ability to adhere to schedule.

Cost Drivers – Project Characteristics.

Project Characteristics Table

Cost adjustments for computing the EAF (Effort Adjustment Factor)

	v.low	low	nominal	high	v.high	ex.high
product attributes						
required software reliability	0.75	0.88	1.00	1.15	1.40	
database size		0.94	1.00	1.08	1.16	
product complexity	0.70	0.85	1.00	1.15	1.30	1.65
computer attributes						
execution time constraints			1.00	1.11	1.30	1.66
main storage constraints			1.00	1.06	1.21	1.56
virtual machine volitility	0.87	1.00	1.15	1.30		
computer turnaround time		0.87	1.00	1.07	1.15	
personnel attributes						
analyst capability	1.46	1.19	1.00	0.86	0.71	
applications experience	1.29	1.13	1.00	0.91	0.82	
programmer capability	1.42	1.17	1.00	0.86	0.70	
virtual machine experience	1.21	1.10	1.00	0.90		
programming language experience	1.14	1.07	1.00	0.95		
project attributes						
use of modern programming practices	1.24	1.10	1.00	0.91	0.82	
use of software tools	1.24	1.10	1.00	0.91	0.83	
required development schedule	1.23	1.08	1.00	1.04	1.10	

2.3 Advanced COCOMO Model.

(a.k.a. Model 3).

This model incorporates all characteristics of the intermediate version with an assessment of the cost driver's impact on each phase distribution (analysis, design, develop, implement, test, produce, etc.) of the software engineering process.

3 COCOMO Equations (formulae).

We shall see the COCOMO equations model by model.

1. **Basic Model**
2. **Intermediate Model.**
3. **Advanced model.**

3.1 Equations For Basic COCOMO Model.

Following is the format for this model:

$$MM = a \times (KDSI)^b$$ [Man months or the effort]

$$T_{dev} = c \times (MM)^d$$ [Time for development.]

Expressed in calendar months.

a, c are scaling factors for code size and effort size respectively.

b, d are scaling exponents for code size & effort size respectively.

Values of a, b, c, & d can be picked from the table below:

Project Mode	a	b	c	d
Organic	2.4	1.05	2.5	0.38
Semi-detached	3.0	1.12	2.5	0.25
Embedded	3.6	1.20	2.5	0.32

Trick: Number of people needed = MM / T_{dev}

3.2 Equations For Intermediate COCOMO Model.

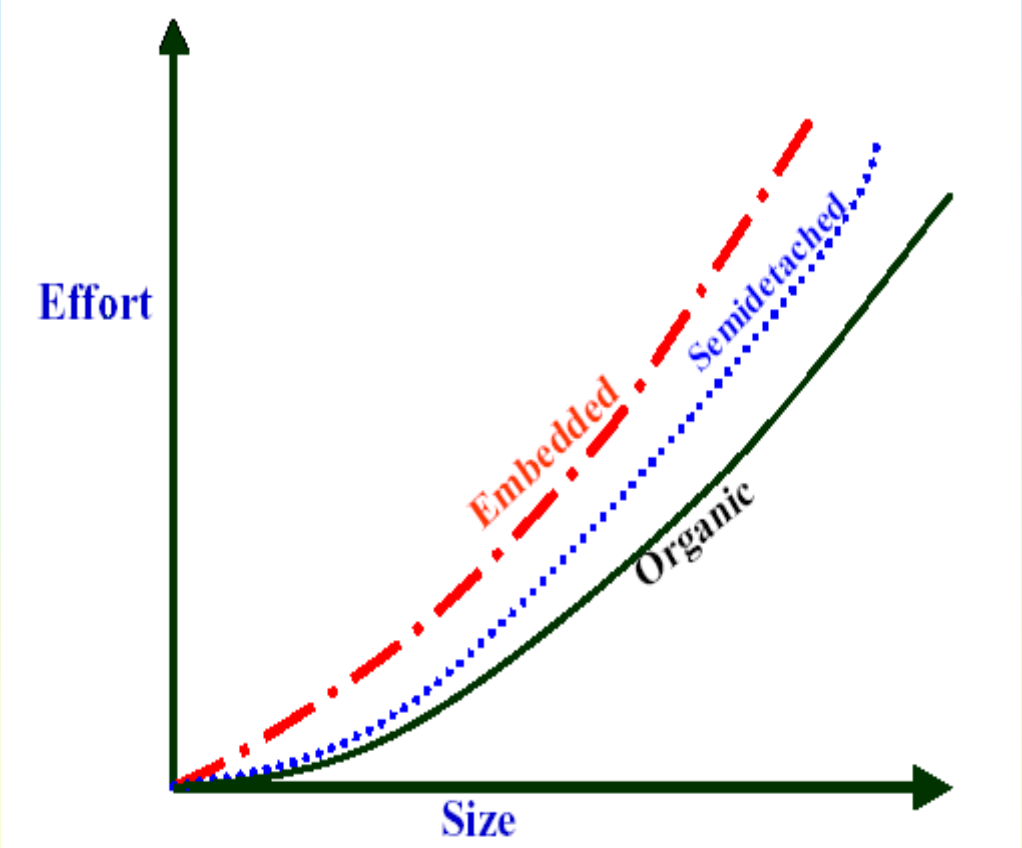
Following is the format for this model:

$$MM = a \times (KDSI)^b \times EAF$$

$$T_{dev} = c \times (MM)^d$$ (same as basic model)

Values of a & b are given by the table below:

Project Mode	a	b
Organic	3.2	1.05
Semi-detached	3.0	1.12
Embedded	2.8	1.20


Effort
Size
Embedded
Semidetached
Organic

COCOMO Example

Model: Intermediate COCOMO.

Consider a database system needed for an office automation project. The requirements study shows the need of the following four clear modules. A size estimator has calculated size estimates for each of these modules as following:

Module	Size (KDSI)
Data entry	0.6
Data update	0.6
Query	0.8
Report Gen	1.0

The project characteristics are rated as follows:

Characteristic	Level
Complexity	High
Storage	High
Applications Experience	Low
Programmer Capabilities	Low
All others	Nominal

Find the following:

(a) Project Mode (Organic / Semi-detached / Embedded).

(b) Effort (Person months) for the project.

(c) What will be the duration estimate?

(d) How many people are required?

(e) Calculate development cost if effort each developer rate is Rs. 1000.00 per hour

COCOMO Example – Solution.

Given Model: Intermediate COCOMO.

(a) Project team will work in a familiar environment.
The project work appears to be well-understood to the team.
The number of modules also indicates that the project mode is organic.

(b) Person Months (Effort)
The effort size estimate is the total of module size in KDSI.

Module	Size (KDSI)
Data entry	0.6
Data update	0.6
Query	0.8
Report Gen	1.0
Total	**3.0 KDSI**.

The project characteristics rating factors are: (see the characteristics table)

Characteristic	Level	Factor
Complexity	High	1.15
Storage	High	1.06
Applications Experience	Low	1.13
Programmer Capabilities	Low	1.17
All Others	Nominal	1.0

→**Continued on next page**

COCOMO Example – Solution.

(b) Person Months (Continued)

To find EAF multiply all characteristic rating values together.

EAF = 1.15 X 1.06 X 1.13 X 1.17 X 1 = 1.61

As the project mode is organic, we use the intermediate COCOMO effort equation:

$PM \text{ or } MM = a \text{ X } (KDSI)^b \text{ X } EAF$ (where a=3.2, b=1.05)

➔ PM or MM = 3.2 X $(3.0)^{1.05}$ X 1.61 = 3.2 X 3.17 X 1.61 = 16.33

Thus the project effort > 16 person months.

(c) Duration (Time for development)

Use the organic mode intermediate COCOMO duration equation:

$$T_{dev} = c \text{ X } (MM)^d \text{ (where c = 2.5, d=0.38)}$$

So duration is calculated as:

$$2.5 \text{ X } (16.33)^{0.38} = 2.5 \text{ X } 2.89 = 7.23$$

Thus project duration > 7 months.

COCOMO Example – Solution.

(d) Team size (number of people).

Number of people needed is given by equation:

$$\mathbf{MM / T_{dev}}$$

So duration is calculated as: 16.33 / 7.23 = 2.26

Thus team size = 2 or 3 people.

(e) Development Cost

Developer Rate = Rs 1000 per hour

Number of developers = 3 (Case #1)

Number of developers = 2 (Case #2)

Case #1 – With 3 developers (one month)

Cost = 3 x 160 x 1000 = Rs. 4,80,000

Case #2 – With 2 developers (one month)

Cost = 2 x 160 x 1000 = Rs. 3,20,000

You can calculate total development cost by multiplying cost with 7 or 8 (months)

How to Calculate Man Hours

- **When planning for a major project or establishing annual goals, looking at the costs of workers/people is essential to determining whether you will be able to meet your financial goals. Looking at man hours in terms of standard worker costs and overtime wages helps managers keep budgets accurate and on track.**

Step 1

- **Look at the calendar for the time period in question. For an annual budget, remove all non-working days from the work year. Do the same for a project planned to be completed over a shorter period of time.**

Step 2

- **Assume you have a 12-week project with employees working a 10-hour day, five days a week. There are two national holidays in the time period when your employees will not work. There are five employees on the job.**

Step 3

- **Multiply the five-day work week by 12 weeks: 12 by 5 = 60. Subtract the two holidays for 58 days. Multiply the number of work days by 10 hours per day: 58 by 10 = 580--these are the project hours per employee.**

Step 4

- **Multiply the per-employee man hours by the number of employees on the job: 580 by 5 = 2,900. There are 2,900 total man hours assigned to this project.**