Software Project Management

Chapter Five

Software effort estimation

What makes a successful project?

Delivering:

- agreed functionality
- on time
- at the agreed cost
- with the required quality

Stages:

1. set targets
2. Attempt to achieve targets

Difficulties in estimating due to complexity and invisibility of software.

BUT what if the targets are not achievable?

Some problems with estimating

- Subjective nature of much of estimating
  - Under estimating the difficulties of small task and over estimating large projects.
- Political pressures
  - Managers may wish to reduce estimated costs in order to win support for acceptance of a project proposal (over estimate to create a comfort zone)
- Changing technologies
  - these bring uncertainties, especially in the early days when there is a ‘learning curve’. Difficult to use the experience of previous projects.
- Projects differ -lack of homogeneity of project experience
  - Experience on one project may not be applicable to another

Exercise:

Calculate the productivity (i.e. SLOC/work month) of each of the projects in Table next slide and also for the organization as a whole. If the project leaders for projects a and d had correctly estimated the source number of lines of code (SLOC) and then used the average productivity of the organization to calculate the effort needed to complete the projects, how far out would their estimate have been from the actual one.

Project	Design		Coding		Testing		Total	
	wm	(%)	wm	(%)	wm	(%)	wm	SLOC
a	3.9	23	5.3	32	7.4	44	16.7	6050
b	2.7	12	13.4	59	6.5	36	22.6	8363
c	3.5	11	26.8	83	1.9	6	32.2	13334
d	0.8	21	2.4	62	0.7	18	3.9	5942
e	1.8	10	7.7	44	7.8	45	17.3	3315
f	19.0	28	29.7	44	19.0	28	67.7	38988
g	2.1	21	7.4	74	0.5	5	10.1	38614
h	1.3	7	12.7	66	5.3	27	19.3	12762
i	8.5	14	22.7	38	28.2	47	59.5	26500

Project	Work-month	SLOC	Productivity (SLOC/month)
a	16.7	6,050	362
b	22.6	8,363	370
c	32.2	13,334	414
d	3.9	5,942	1,524
e	17.3	3,315	192
f	67.7	38,988	576
g	10.1	38,614	3,823
h	19.3	12,762	661
i	59.5	26,500	445
Overall	**249.3**	**153,868**	**617**

Project	Estimated work-month	Actual	Difference
a	6050 / 617 = 9.80	16.7	6.90
d	5942 / 617 = 9.63	3.9	- 5.73

Over and under-estimating

Parkinson’s Law: ‘Work expands to fill the time available’

An over-estimate is likely to cause project to take longer than it would otherwise

Weinberg’s Zeroth Law of reliability: ‘a software project that does not have to meet a reliability requirement can meet any other requirement’

- Brook’s Law: ‘putting more people on a late job makes it later’. If there is an overestimate of the effort required, this could lead to more staff being allocated than needed and managerial overheads being increased.

Basis for successful estimating

- Information about past projects
  - Need to collect performance details about past project: how big were they? How much effort/time did they need?
- Need to be able to measure the amount of work involved
  - Traditional size measurement for software is 'lines of code' (LOC) – but this can have problems
  - FP measure corrects to a great extent.

A taxonomy of estimating methods

Bottom-up - activity based, analytical (WBS – insert, amend, update, display, delete, print)

Parametric or algorithmic models (Top-down approach)

Expert opinion - just guessing?

Analogy - case-based, comparative

Albrecht function point analysis

Parameters to be Estimated

- Size is a fundamental measure of work
- Based on the estimated size, two parameters are estimated:
  - Effort
  - Duration
- Effort is measured in person-months:
  - One person-month is the effort an individual can typically put in a month.

Measure of Work

The project size is a measure of the problem complexity in terms of the effort and time required to develop the product.

Two metrics are used to measure project size:

- Source Lines of Code (SLOC)
- Function point (FP)

FP is now-a-days favored over SLOC:

- Because of the many shortcomings of SLOC.

Major Shortcomings of SLOC

- No precise definition (e.g. comment line, data declaration line to be included or not?)
- Difficult to estimate at start of a project
- Only a code measure
- Programmer-dependent
- Does not consider code complexity

Bottom-up versus top-down

- Bottom-up
  - use when no past project data
  - identify all tasks that have to be done – so quite time-consuming
  - use when you have no data about similar past projects
- Top-down
  - produce overall estimate based on project cost drivers
  - based on past project data
  - divide overall estimate between jobs to be done

Bottom-up estimating

1. Break project into smaller and smaller components

[2. Stop when you get to what one person can do in one/two weeks]

3. Estimate costs for the lowest level activities
4. At each higher level calculate estimate by adding estimates for lower levels

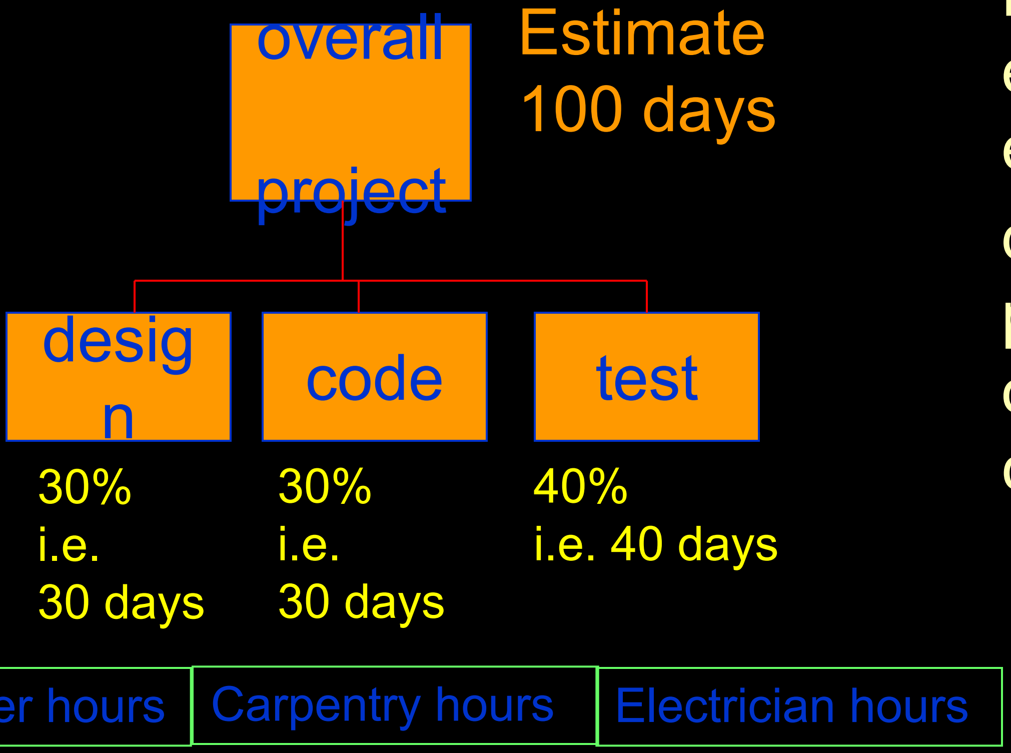
A procedural code-oriented approach

a) Envisage the number and type of modules in the final system
b) Estimate the SLOC of each individual module
c) Estimate the work content
d) Calculate the work-days effort

Top-down estimates

Normally associated with parametric (or algorithmic) model.

Ex: House building project



Produce overall estimate using effort driver(s)

distribute proportions of overall estimate to components

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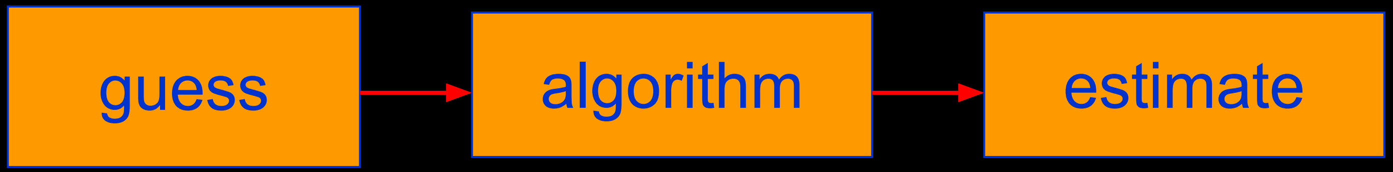
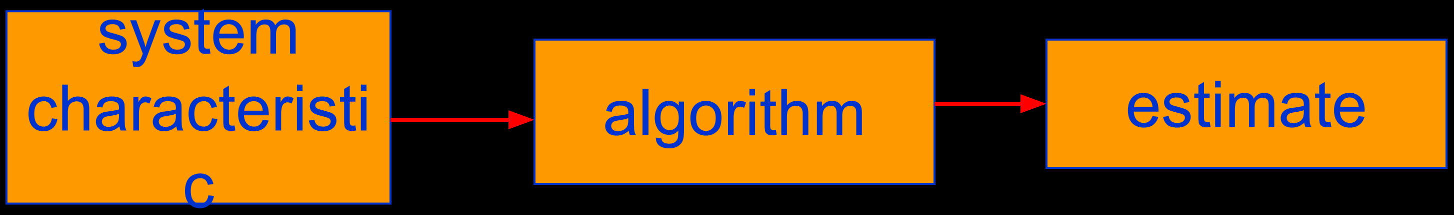
Algorithmic/Parametric models

COCOMO (lines of code) and function points examples of these

Problem with COCOMO etc:



but what is desired is



Parametric models - the need for historical data

simplistic model for an estimate

estimated effort = (system size) / (productivity)

e.g.

system size = lines of code

productivity = lines of code per day

productivity = (system size) / effort

based on past projects

Software size = 2 KLOC

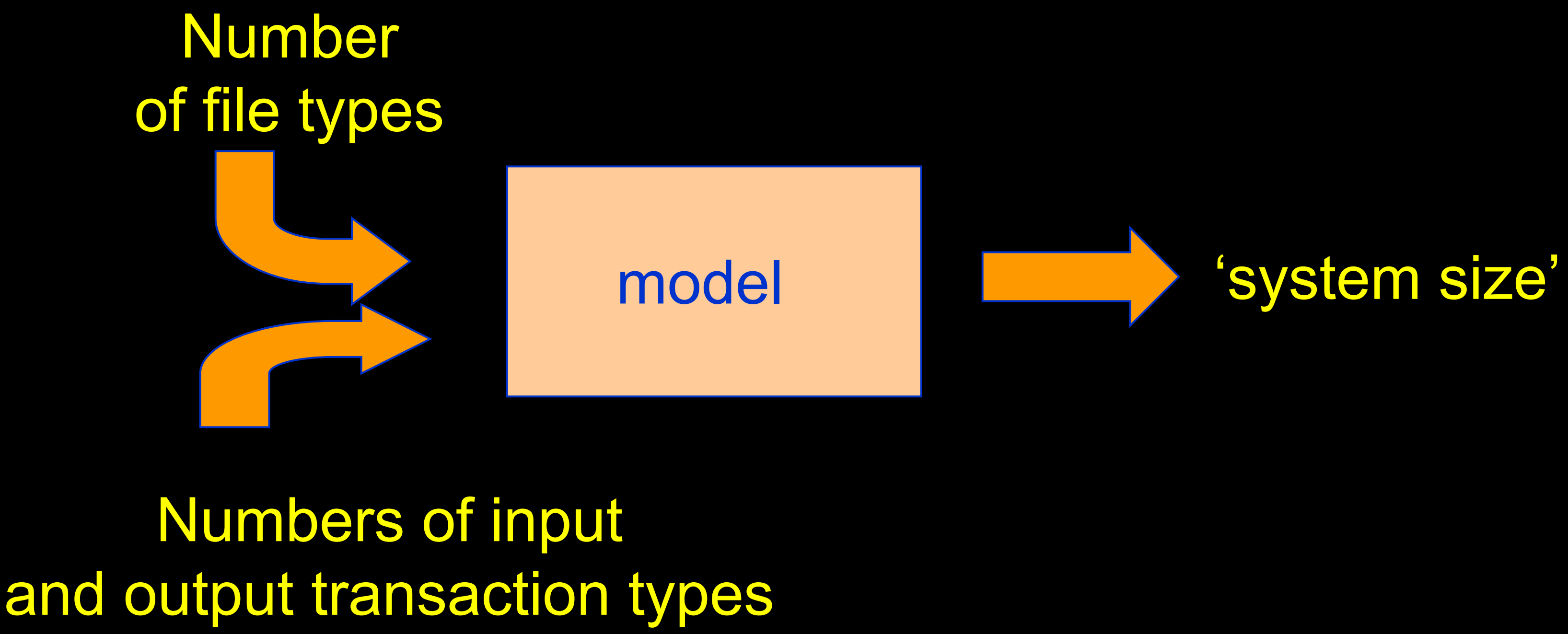
If A (expert) can take 40 days per KLOC $\rightarrow$ 80 days

If B (novice) takes 55 days per KLOC $\rightarrow$ 110 days

KLOC is a size driver, experience influences productivity

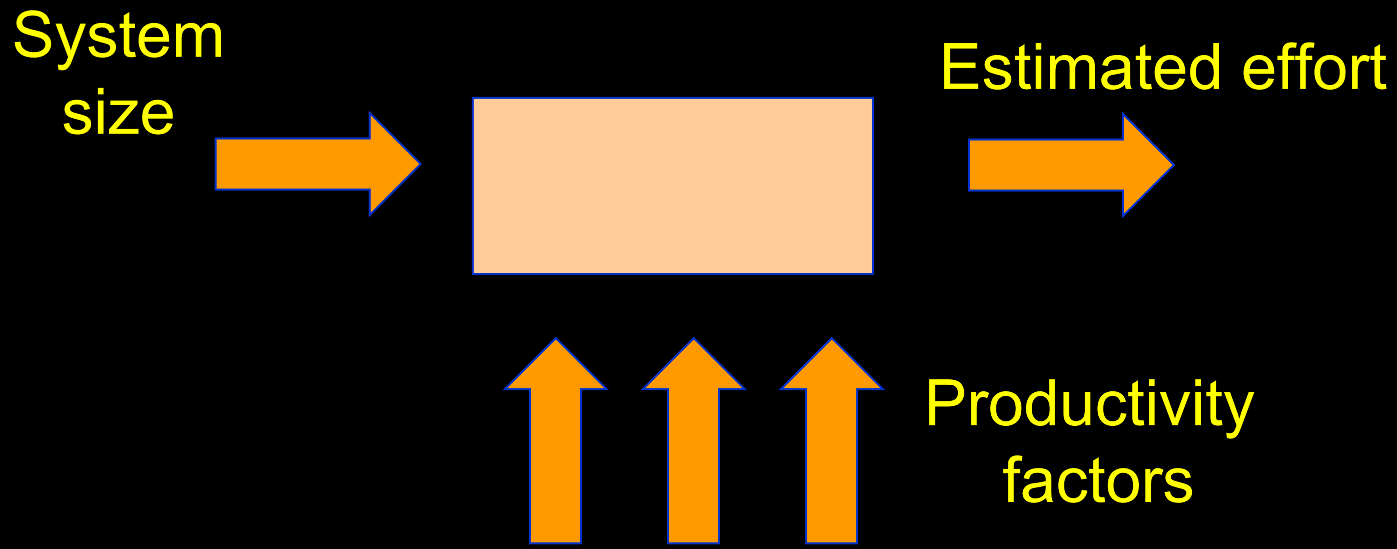
Parametric models

- Some models focus on task or system size e.g. Function Points
- FPs originally used to estimate Lines of Code, rather than effort



Parametric models

Other models focus on productivity: e.g. COCOMO
Lines of code (or FPs etc) an input



Expert judgement

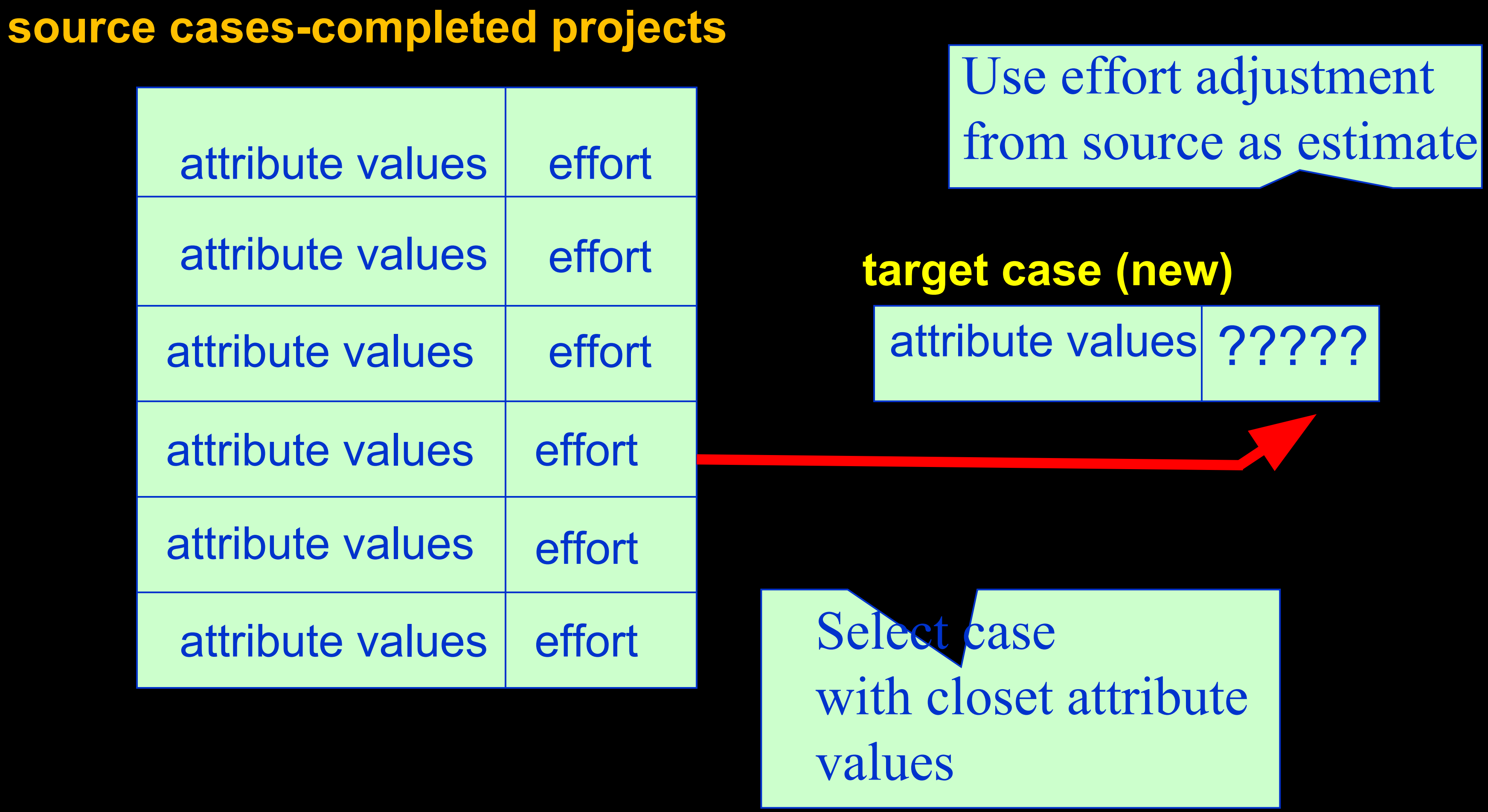
Asking someone who is familiar with and knowledgeable about the application area and the technologies to provide an estimate

Particularly appropriate where existing code is to be modified

Research shows that experts judgement in practice tends to be based on analogy

Note: Delphi technique – group decision making

Estimating by analogy
(Case-based reasoning)



source cases-completed projects

attribute values	effort
attribute values	effort
attribute values	effort
attribute values	effort
attribute values	effort
attribute values	effort

Use effort adjustment from source as estimate

target case (new)

attribute values	?????

Select case with closet attribute values

Estimating by analogy…cont.

Use of ANGEL software tool (measure the Euclidean distance between project cases)

Example:

Say that the cases are being matched on the basis of two parameters, the number of inputs to and the number of outputs from the application to be built. The new project is known to require 7 inputs and 15 outputs. One of the past cases, project A, has 8 inputs and 17 outputs.

The Euclidian distance between the source and the target is therefore = 2.24

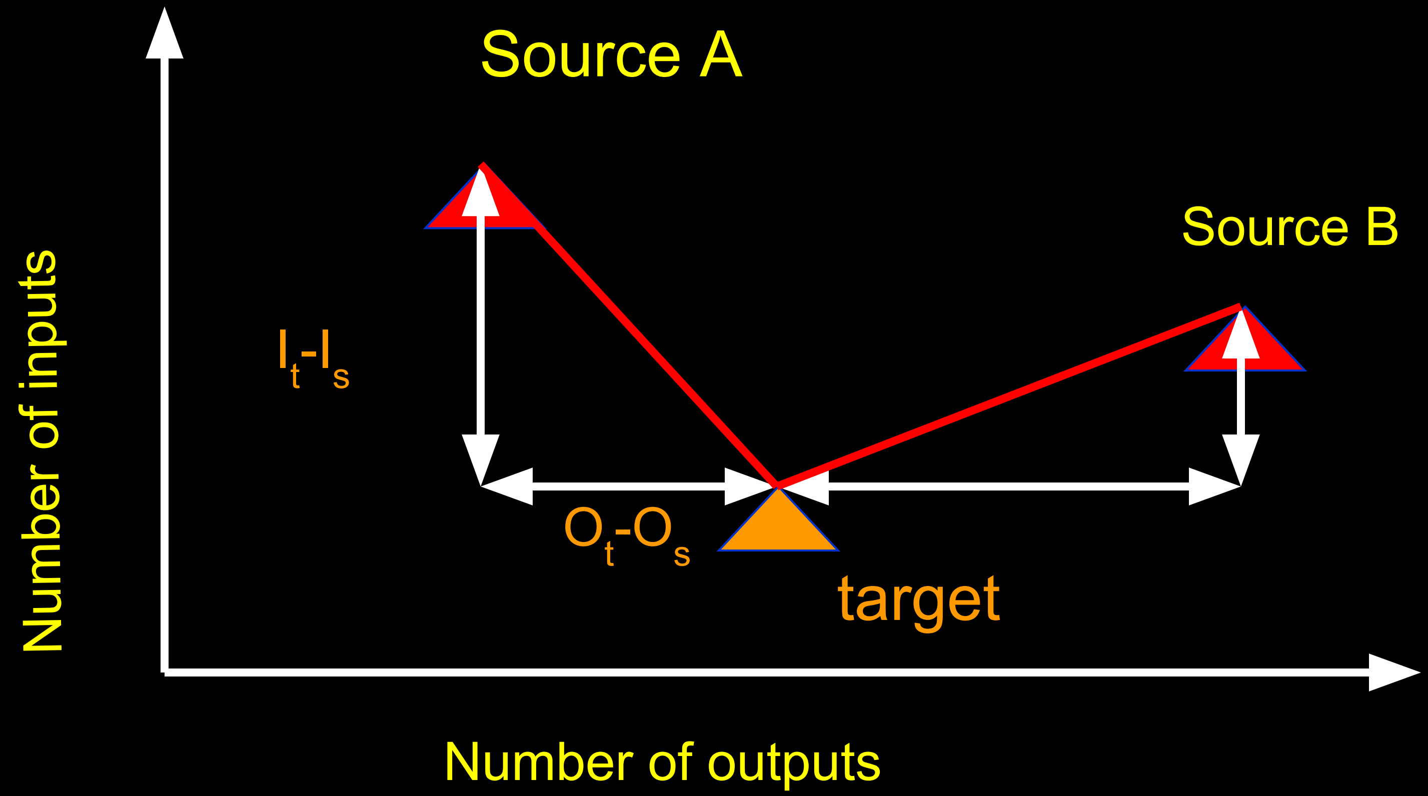
Exercise:

Project B has 5 inputs and 10 outputs. What would be the Euclidian distance between this project and the target new project being considered in the previous slide? Is project B a better analogy with the target than project A?

The Euclidian distance between project B and the target case is = 5.39.

Therefore project A is a closer analogy.

Machine assistance for source selection (ANGEL)



Euclidean distance = sq root $((I_t - I_s)^2 + (O_t - O_s)^2)$

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Stages: identify

Significant features of the current project

previous project(s) with similar features

differences between the current and previous projects

possible reasons for error (risk)

measures to reduce uncertainty

Parametric models

We are now looking more closely at four parametric models:

Albrecht/IFPUG function points

Symons/Mark II function points

COSMIC function points

COCOMO81 and COCOMO II

COSMIC- common software measurement consortium

COCOMO- cost constructive model

IFPUG- international function point user group

Albrecht/IFPUG function points

Albrecht worked at IBM and needed a way of measuring the relative productivity of different programming languages.

Needed some way of measuring the size of an application without counting lines of code.

Identified five types of component or functionality in an information system

Counted occurrences of each type of functionality in order to get an indication of the size of an information system

Note: IFPUG- International FP User Group

Albrecht/IFPUG function points - continued

Five function types

1. Logical internal file (LIF) types – equates roughly to a data store in systems analysis terms. Created and accessed by the target system

   (it refers to a group data items that is usually accessed together i.e. one or more record types)

   PURCHASE-ORDER and PURCHASE-ORDER-ITEM
2. External interface file types (EIF) – where data is retrieved from a data store which is actually maintained by a different application.

Albrecht/IFPUG function points - continued

3. External input (EI) types – input transactions which update internal computer files
4. External output (EO) types – transactions which extract and display data from internal computer files. Generally involves creating reports.
5. External inquiry (EQ) types – user initiated transactions which provide information but do not update computer files. Normally the user inputs some data that guides the system to the information the user needs.

Albrecht complexity multipliers

Table-1

External user types	Low complexity	Medium complexity	High complexity
EI External input type	3	4	6
EO External output type	4	5	7
EQ External inquiry type	3	4	6
LIF Logical internal file type	7	10	15
EIF External interface file type	5	7	10

With FPs originally defined by Albecht, the external user type is of high, low or average complexity is intuitive. Ex: in the case of logical internal files and external interface files, the boundaries shown in table below are used to decide the complexity level.

Table-2

Number of record types	Number of data types		
	< 20	20 – 50	> 50
1	Low	Low	Average
2 to 5	Low	Average	High
> 5	Average	High	High

Example

A **logical internal file** might contain data about purchase orders. These purchase orders might be organized into two separate record types: the main PURCHASE-ORDER details, namely purchase order number, supplier reference and purchase order date.

The details of PURCHASE-ORDER-ITEM specified in the order, namely the product code, the unit price and number ordered.

- The number of record types for this will be 2
- The number of data types will be 6
- According to the previous table-2 file type will be rated as ‘Low’
- According to the previous table-1 the FP count is 7

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Examples

Payroll application has:

1. Transaction to input, amend and delete employee details – an EI that is rated of medium complexity
2. A transaction that calculates pay details from timesheet data that is input – an EI of high complexity
3. A transaction of medium complexity that prints out pay-to-date details for each employee – EO
4. A file of payroll details for each employee – assessed as of medium complexity LIF
5. A personnel file maintained by another system is accessed for name and address details – a simple EIF

What would be the FP counts for these?

FP counts

Refer Table-1

Medium EI	4 FPs
High complexity EI	6 FPs
Medium complexity EO	5 FPs
Medium complexity LIF	10 FPs
Simple EIF	5 FPs
Total	30 FPs

If previous projects delivered 5 FPs a day, implementing the above should take 30/5 = 6 days

Function points Mark II

Developed by Charles R. Symons

‘Software sizing and estimating - Mk II FPA’, Wiley & Sons, 1991.

Builds on work by Albrecht

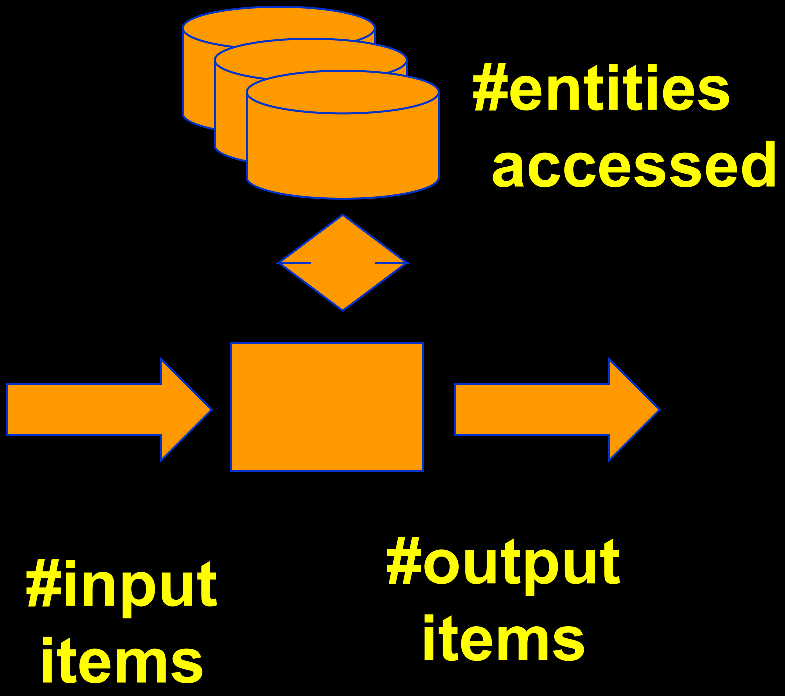
Work originally for CCTA:

- should be compatible with SSADM; mainly used in UK

has developed in parallel to IFPUG FPs

A simpler method

Function points Mk II continued



For each transaction, count

- data items input (N_i)
- data items output (N_o)
- entity types accessed (N_e)

FP count = N_i * 0.58 + N_e * 1.66 + N_o * 0.26

UFP – Unadjusted Function Point – Albrecht (information processing size is measured)

TCA – Technical Complexity Adjustment (the assumption is, an information system comprises transactions which have the basic structures, as shown in previous slide)

For each transaction the UFPs are calculated:

W_i X *(number of input data element types)* + W_e X *(number of entity types referenced)* + W_o X *(number of output data element types)*

W_i ,W_e ,W_o are weightings derived by asking developers the proportions of effort spent in previous projects developing the code dealing with input, accessing stored data and outputs.

W_i = 0.58, W_e = 1.66, W_o = 0.26 (industry average)

Exercise:

A cash receipt transaction in an accounts subsystem accesses two entity types INVOICE and CASH-RECEIPT.

The data inputs are:

Invoice number Date received

Cash received

If an INVOICE record is not found for the invoice number then an error message is issued. If the invoice number is found then a CASH-RECEIPT record is created. The error message is the only output of the transaction. Calculate the unadjusted function points, using industry average weightings, for this transaction.

(0.58 X 3) + (1.66 X 2) + (0.26 X 1) = 5.32

Exercise:

In an annual maintenance contract subsystem is having a transaction which sets up details of new annual maintenance contract customers.

1. Customer account number 2.Customer name 3. Address 4. Postcode 5. Customer type 6. Renewal date

All this information will be set up in a CUSTOMER record on the system's database. If a CUSTOMER account already exists for the account number that has been input, an error message will be displayed to the operator.

Calculate the number of unadjusted Mark II function points for the transaction described above using the industry average.

Answer:

The function types are:

Input data types	6
Entities accessed	1
Output data types	1

UFP = Unadjusted function points

= (0.58 X 6) + (1.66 X 1) + (0.26 X 1)

= 5.4

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Function points for embedded systems

- Mark II function points, IFPUG function points were designed for information systems environments
- They are not helpful for sizing real-time or embedded systems
- COSMIC-FFPs (common software measurement consortium-full function point) attempt to extend concept to embedded systems or real-time systems
- FFP method origins the work of two interlinked groups in Quebec, Canada
- Embedded software seen as being in a particular 'layer' in the system
- Communicates with other layers and also other components at same level

The argument is

- existing function point method is effective in assessing the work content of an information system.
- size of the internal procedures mirrors the external features.
- in real-time or embedded system, the features are hidden because the software's user will probably not be human beings but a hardware device.

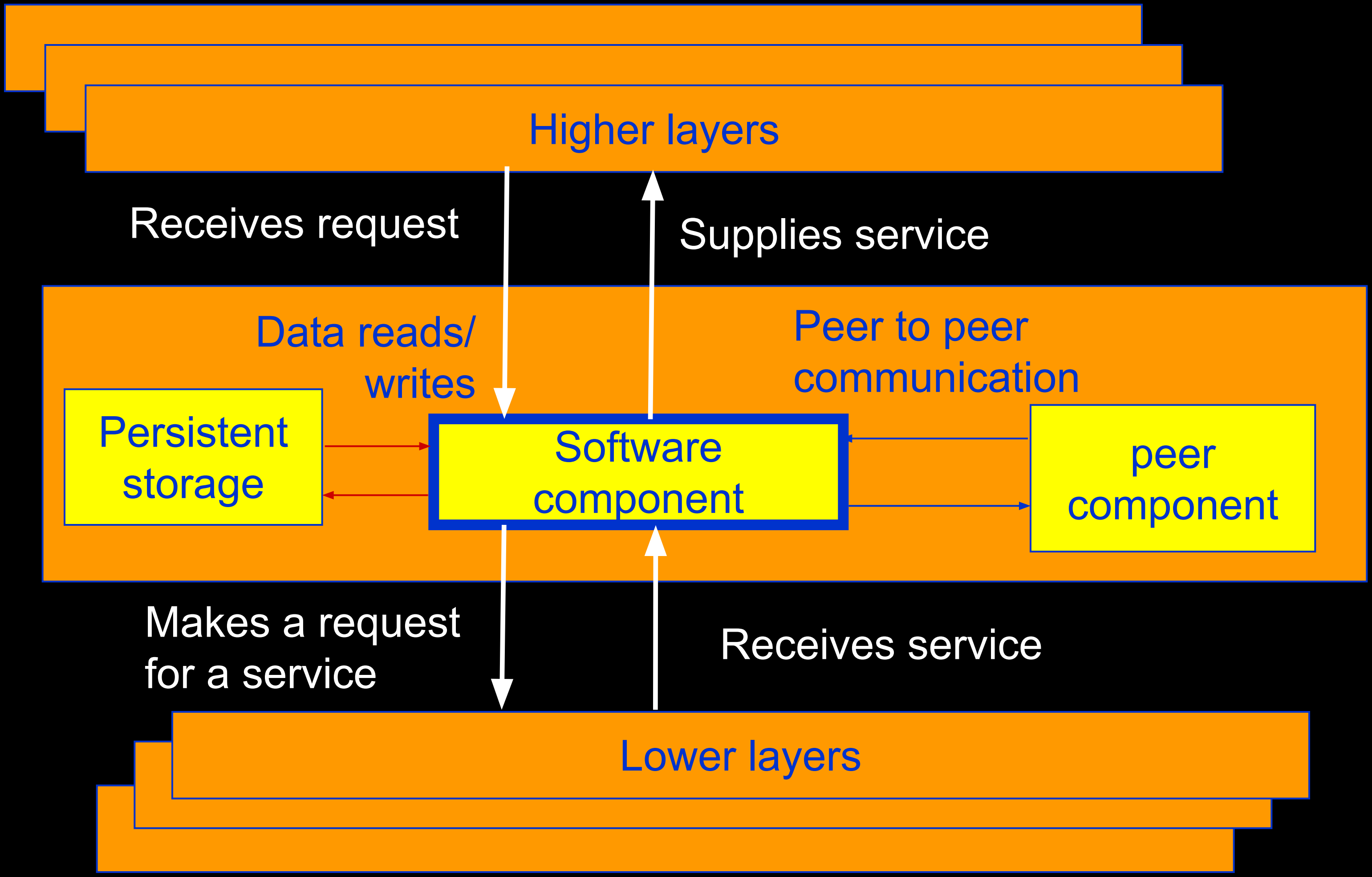
COSMIC deals with by decomposing the system architecture into a hierarchy of software layers.

The software component to be sized can receive requests the service from layers above and can request services from those below.

There may be separate software components engage in peer-to-peer communication.

Inputs and outputs are aggregated into data groups, where each data group brings together data items related to the same objects.

Layered software



COSMIC FPs

The following are counted: (Data groups can be moved in four ways)

Entries (E): movement of data into software component from a higher layer or a peer component

Exits (X): movements of data out to a user outside its boundary

Reads (R): data movement from persistent storage

Writes (W): data movement to persistent storage

Each counts as 1 ‘COSMIC functional size unit’ (Cfsu). The overall FFP count is derived by simply adding up the counts for each of the four types of data movement.

Exercise:

A small computer system controls the entry of vehicles to a car park. Each time a vehicle pulls up before an entry barrier, a sensor notifies the computer system of the vehicle's presence. The system examines a count that it maintains the number of vehicles currently in the car park. This count is kept on the backing storage so that it will still be available if the system is temporarily shut down, for example because of a power cut. If the count does not exceed the maximum allowed then the barrier is lifted and count is incremented. When the vehicle leaves the car park, a sensor detects the exit and reduce the count of vehicles.

Identify the entries, exits, reads and writes in this application.

Data movement	Type
Incoming vehicles sensed	
Access vehicle count	
Signal barrier to be lifted	
Increment vehicle count	
Outgoing vehicle sensed	
Decrement vehicle count	
New maximum input	
Set new maximum	
Adjust current vehicle count	
Record adjusted vehicle count	

Data movement	Type
Incoming vehicles sensed	E
Access vehicle count	R
Signal barrier to be lifted	X
Increment vehicle count	W
Outgoing vehicle sensed	E
Decrement vehicle count	W
New maximum input	E
Set new maximum	W
Adjust current vehicle count	E
Record adjusted vehicle count	W

Note: different interpretations of the requirements could lead to different counts. The description in the exercise does not specify to give a message that the car park is full or has spaces.

COCOMO81

Based on industry productivity standards - database is constantly updated

Allows an organization to benchmark its software development productivity

Basic model

effort = c x size^{k}

C and k depend on the type of system: organic, semi-detached, embedded

Size is measured in ‘kloc’ ie. Thousands of lines of code

Boehm in 1970, on a study of 63 projects, made this model. Of these only seven were business systems and so the model was based on other applications (non-information systems).

The COCOMO constants

System type	c	k
Organic (broadly, information systems, small team, highly familiar in-house environment)	2.4	1.05
Semi-detached (combined characteristics between organic and embedded modes)	3.0	1.12
Embedded (broadly, real-time, products developed has to operate within very tight constraints and changes to system is very costly)	3.6	1.20

k exponentiation – ‘to the power of…’
adds disproportionately more effort to the larger projects
takes account of bigger management overheads

$$\text{effort} = c\,(\text{size})^k$$

effort – pm (person month) – 152 working hours

size – KLOC – kdsi (thousands of delivered source code instruction)

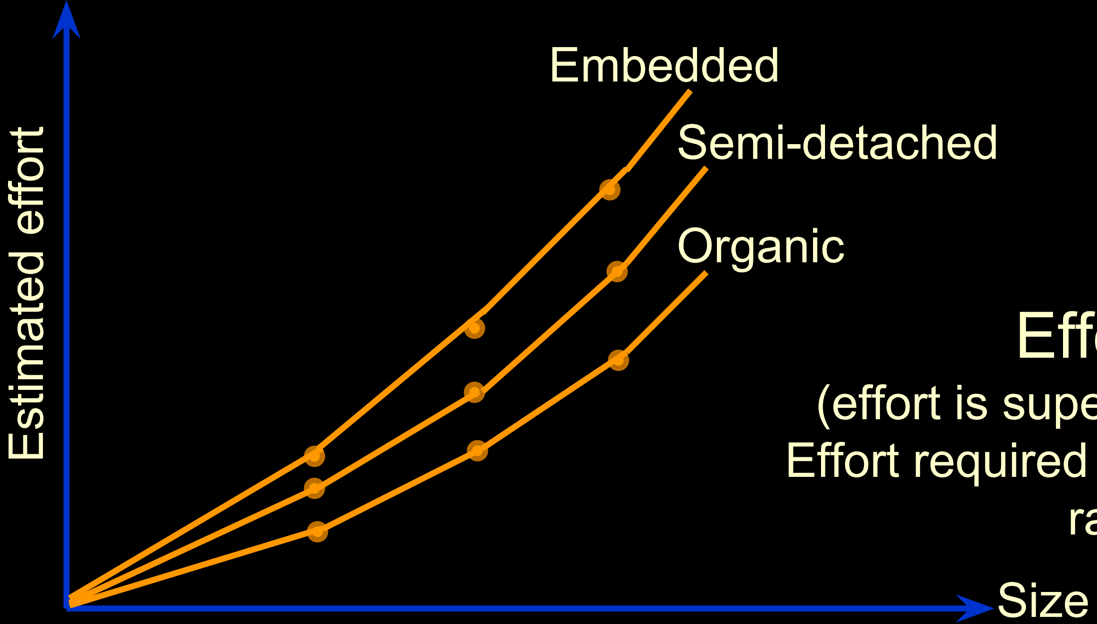
c and k – constants depending on whether the system is organic, semi-detached or embedded.

Organic	: $\text{Effort} = 2.4(\text{KLOC})^{1.05}$ PM
Semidetached	: $\text{Effort} = 3.0(\text{KLOC})^{1.12}$ PM
Embedded	: $\text{Effort} = 3.6(\text{KLOC})^{1.20}$ PM

Estimation of development time

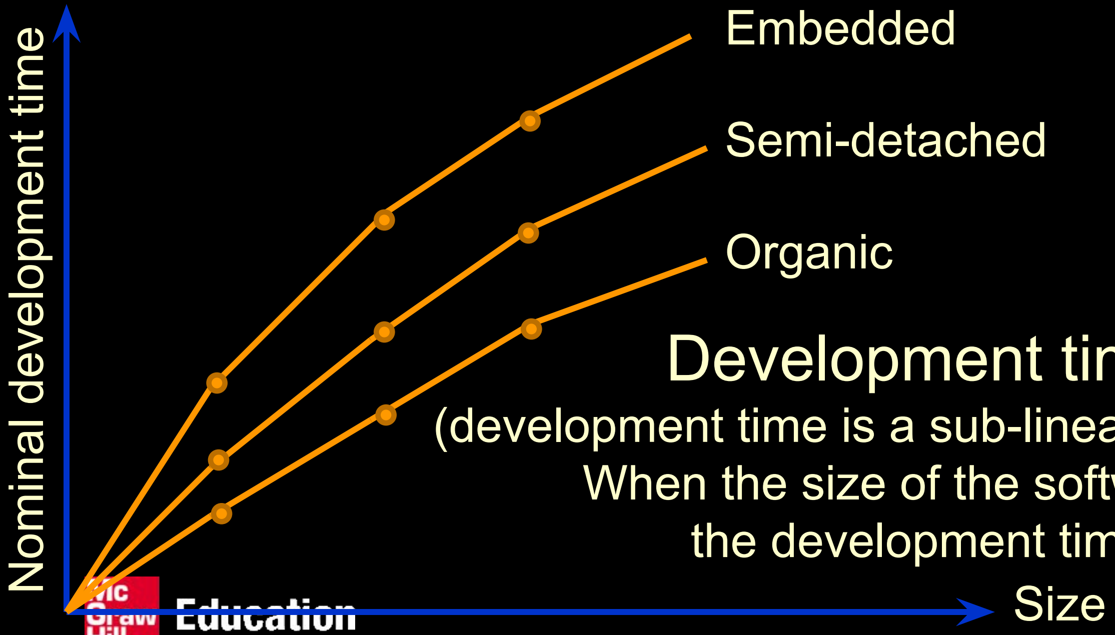
$$T_{dev} = a \times (\text{Effort})^b$$

Organic	: $2.5(\text{Effort})^{0.38}$
Semidetached	: $2.5(\text{Effort})^{0.35}$
Embedded	: $2.5(\text{Effort})^{0.32}$



Effort vs. product size

(effort is super-linear in the size of the software)
Effort required to develop a product increases very rapidly with project size.



Development time vs. product size

(development time is a sub-linear function of the size of the product)
When the size of the software increases by two times,
the development time increases moderately

Exercise:

Assume that the size of an organic type software product is estimated to be 32,000 lines of source code. Assume that the average salary of a software developer is Rs.50,000 per month. Determine the effort required to develop the software product, the nominal development time, and the staff cost to develop the product.

Effort = 2.4 X $32^{1.05}$ = 91 pm

Nominal development time = 2.5 X $91^{0.38}$ = 14 months

Staff cost required to develop the product

91 X Rs. 50,000 = Rs. 45,50,000

Ex-*Two software managers separately estimated a given product to be of 10,000 and 15,000 lines of code respectively. Bring out the effort and schedule time implications of their estimation using COCOMO. For the effort estimation, use a coefficient value of 3.2 and exponent value of 1.05. For the schedule time estimation, the similar values are 2.5 and 0.38 respectively. Assume all adjustment multipliers to be equal to unity.*

For 10,000 LOC

Effort = $3.2 \times 10^{1.05} = 35.90$ PM

Schedule Time = $T_{dev} = 2.5 \times 35.90^{0.38} = 9.75$ months

For 15,000 LOC

Effort = $3.2 \times 15^{1.05} = 54.96$ PM

Schedule Time = $T_{dev} = 2.5 \times 54.96^{0.38} = 11.46$ months

NB: Increase in size drastic increase in effort but moderate change in time.

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COCOMO II

An updated version of COCOMO:

There are different COCOMO II models for estimating at the 'early design' stage and the 'post architecture' stage when the final system is implemented. We'll look specifically at the first.

The core model is:

$pm = A(size)^{(sf)} \times (em_1) \times (em_2) \times (em_3) \ldots.$

where **pm** = person months, **A** is 2.94, **size** is number of thousands of lines of code, **sf** is the scale factor, and **em** is an effort multiplier

sf = B + 0.01 X Σ (*exponent driver ratings*)

COCOMO II Scale factor

Boehm et al. have refined a family of cost estimation models. The key one is COCOMO II. It uses multipliers and exponent values. Based on five factors which appear to be particularly sensitive to system size.

Precedentedness (PREC). Degree to which there are past examples that can be consulted, else uncertainty

Development flexibility (FLEX). Degree of flexibility that exists when implementing the project

Architecture/risk resolution (RESL). Degree of uncertainty about requirements, liable to change

Team cohesion (TEAM). Large dispersed

Process maturity (PMAT) could be assessed by CMMI, more structured less uncertainty

– see Section 13.8

COCOMO II Scale factor values

Driver	Very low	Low	Nominal	High	Very high	Extra high
PREC	6.20	4.96	3.72	2.48	1.24	0.00
FLEX	5.07	4.05	3.04	2.03	1.01	0.00
RESL	7.07	5.65	4.24	2.83	1.41	0.00
TEAM	5.48	4.38	3.29	2.19	1.10	0.00
PMAT	7.80	6.24	4.68	3.12	1.56	0.00

Example of scale factor

A software development team is developing an application which is very similar to previous ones it has developed.

A very precise software engineering document lays down very strict requirements. PREC is very high (score 1.24).

FLEX is very low (score 5.07).

The good news is that these tight requirements are unlikely to change (RESL is high with a score 2.83).

The team is tightly knit (TEAM has high score of 2.19), but processes are informal (so PMAT is low and scores 6.24)

Scale factor calculation

The formula for sf is

sf = B + 0.01 × Σ scale factor values

i.e. sf = 0.91 + 0.01 × (1.24 + 5.07 + 2.83 + 2.19 + 6.24)

= 1.0857

If system contained 10 kloc then estimate would be *effort* = *c* *(size)*^{k} = 2.94 x $10^{1.0857}$ = 35.8 person-months

Using exponentiation ('to the power of') adds disproportionately more to the estimates for larger applications

B = 0.91(constant), c = 2.94 (average)

Exercise:

A new project has ‘average’ novelty for the software supplier that is going to execute it and thus given a nominal rating on this account for precedentedness. Development flexibility is high, requirements may change radically and so risk resolution exponent is rated very low. The development team are all located in the same office and this leads to team cohesion being rated as vey high, but the software house as a whole tends to be very informal in its standards and procedures and the process maturity driver has therefore been given a rating of ‘low’.

(i) What would be the scale factor (*sf*) in this case?

(ii) What would the estimate effort if the size of the application was estimated as in the region of 2000 lines of code?

Assessing the scale factors

Factor	Rating	Value
PREC	nominal	3.72
FLEX	high	2.03
RESL	very low	7.07
TEAM	very high	1.10
PMAT	low	6.24

(i) The overall scale factor = *sf* = B + 0.01 X Σ (exponent factors)
= 0.91 + 0.01 X (3.72 + 2.03 + 7.07 + 1.10 + 6.24
= 0.91 + 0.01 X 20.16 = 1.112

(ii) The estimated effort = c (size)^{k} = 2.94 X 2$^{1.112}$ = 6.35 staff-months

Effort multipliers
(COCOMO II - early design)

As well as the scale factor effort multipliers are also assessed:

RCPX	Product reliability and complexity
RUSE	Reuse required
PDIF	Platform difficulty
PERS	Personnel capability
PREX	Personnel experience
FCIL	Facilities available
SCED	Schedule pressure

Effort multipliers
(COCOMO II - early design)

Table-3

	Extra low	Very low	Low	Nom-in al	High	Very high	Extra high
RCPX	0.49	0.60	0.83	1.00	1.33	1.91	2.72
RUSE			0.95	1.00	1.07	1.15	1.24
PDIF			0.87	1.00	1.29	1.81	2.61
PERS	2.12	1.62	1.26	1.00	0.83	0.63	0.50
PREX	1.59	1.33	1.12	1.00	0.87	0.74	0.62
FCIL	1.43	1.30	1.10	1.00	0.87	0.73	0.62
SCED		1.43	1.14	1.00	1.00	1.00	

Example

Say that a new project is similar in most characteristics to those that an organization has been dealing for some time

except

the software to be produced is exceptionally complex and will be used in a safety critical system.

The software will interface with a new operating system that is currently in beta status.

To deal with this the team allocated to the job are regarded as exceptionally good, but do not have a lot of experience on this type of software.

Example -continued

Refer Table-3

RCPX	very high	1.91
PDIF	very high	1.81
PERS	extra high	0.50
PREX	nominal	1.00

All other factors are nominal

Say estimate is 35.8 person months

With effort multipliers this becomes 35.8 x 1.91 x 1.81 x 0.5
= 61.9 person months

Exercise:

A software supplier has to produce an application that controls a piece of equipment in a factory. A high degree of reliability is needed as a malfunction could injure the operators. The algorithms to control the equipment are also complex. The product reliability and complexity are therefore rates as very high. The company would lie to take opportunity to exploit fully the investment that they made in the project by reusing the control system, with suitable modifications, on future contracts. The reusability requirement is therefore rate as very high. Developers are familiar with the platform and the possibility of potential problems in that respect is regarded as low. The current staff are generally very capable and are rated as very high, but the project is in a somewhat novel application domain for them so experience s rated as nominal. The toolsets available to the developers are judged to be typical for the size of company and are rated nominal, as it is the degree of schedule pressure to meet a deadline

Given the data table-3

(i) What would be the value for each of the effort multipliers?

(ii) What would be the impact of all the effort multipliers on a project estimated as taking 200 staff members?

Factor	Description	Rating	Effort multiplier
RCPX	Product reliability and complexity		
RUSE	Reuse		
PDIF	Platform difficulty		
PERS	Personnel capability		
PREX	Personnel experience		
FCIL	Facilities available		
SCED	Required development schedule		

Factor	Description	Rating	Effort multiplier
RCPX	Product reliability and complexity	Very high	
RUSE	Reuse	Very high	
PDIF	Platform difficulty	Low	
PERS	Personnel capability	Very high	
PREX	Personnel experience	Nominal	
FCIL	Facilities available	Nominal	
SCED	Required development schedule	nominal	

Factor	Description	Rating	Effort multiplier
RCPX	Product reliability and complexity	Very high	1.91
RUSE	Reuse	Very high	1.15
PDIF	Platform difficulty	Low	0.87
PERS	Personnel capability	Very high	0.63
PREX	Personnel experience	Nominal	1.00
FCIL	Facilities available	Nominal	1.00
SCED	Required development schedule	nominal	1.00

New development effort multipliers (dem)

According to COCOMO, the major productivity drivers include:

Product attributes: required reliability, database size, product complexity

Computer attributes: execution time constraints, storage constraints, virtual machine (VM) volatility

Personnel attributes: analyst capability, application experience, VM experience, programming language experience

Project attributes: modern programming practices, software tools, schedule constraints

COCOMO II Post architecture effort multipliers

Modifier type	Code	Effort multiplier
Product attributes	RELY	Required software reliability
	DATA	Database size
	DOCU	Documentation match to life-cycle needs
	CPLX	Product complexity
	REUSE	Required reusability
Platform attributes	TIME	Execution time constraint
	STOR	Main storage constraint
	PVOL	Platform volatility
Personnel attributes	ACAP	Analyst capability
	AEXP	Application experience
	PCAP	Programmer capabilities
	PEXP	Platform experience
	LEXP	Programming language experience
	PCON	Personnel continuity
Project attributes	TOOL	Use of software tools
	SITE	Multisite development
	SCED	Schedule pressure

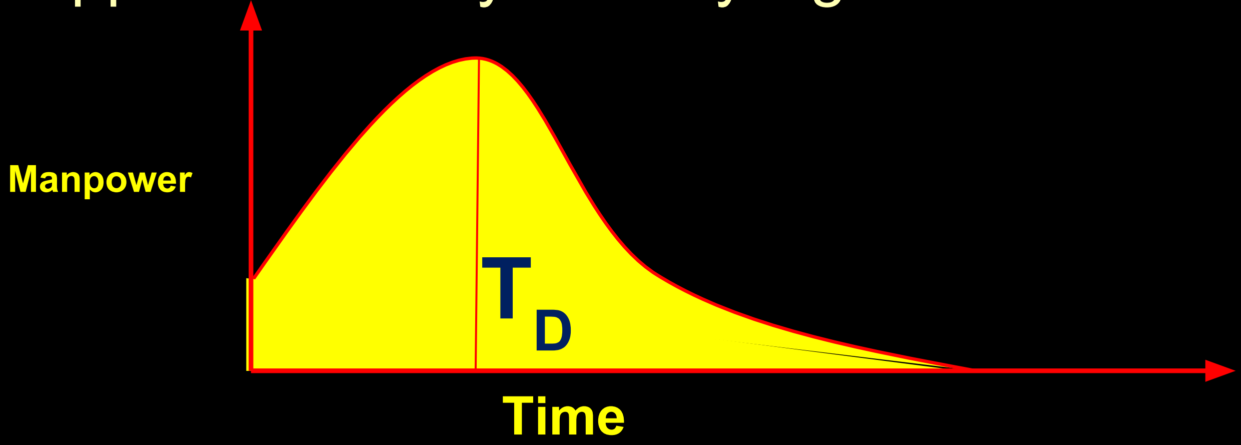
Staffing

Norden was one of the first to investigate staffing pattern:

- Considered general research and development (R&D) type of projects for efficient utilization of manpower.

Norden concluded:

- Staffing pattern for any R&D project can be approximated by the Rayleigh distribution curve



Rayleigh-Norden Curve

Putnam's Work

Putnam adapted the Rayleigh-Norden curve:

- Related the number of delivered lines of code to the effort and the time required to develop the product.
- Studied the effect of schedule compression:

Example

If the estimated development time using COCOMO formulas is 1 year:

Then to develop the product in 6 months, the total effort required (and hence the project cost) increases by

16 times.

Why?

The extra effort can be attributed to the increased communication requirements and the free time of the developers waiting for work.

The project manager recruits a large number of developers hoping to complete the project early, but becomes very difficult to keep these additional developers continuously occupied with work.

Implicit in the schedule and duration estimated arrived at using COCOMO model, is the fact that all developers can continuously be assigned work.

However, when a large number of developers are hired to decrease the duration significantly, it becomes difficult to keep all developers busy all the time. The simultaneous work is getting restricted.

Exercise:

The nominal effort and duration of a project is estimated to be 1000 pm and 15 months. This project is negotiated to be £200,000. This needs the product to be developed and delivered in 12 months time. What is the new cost that needs to be negotiated.

The project can be classified as a large project. Therefore the new cost to be negotiated can be given by Putnam's formula as

New Cost = £200,000 X $(15/12)^4$ = £488,281

Boehm's Result

There is a limit beyond which a software project cannot reduce its schedule by buying any more personnel or equipment.

- This limit occurs roughly at 75% of the nominal time estimate for small and medium sized projects
- If a project manager accepts a customer demand to compress the development schedule of a project (small or medium) by more than 25% , he is very unlikely to succeed.
- The reason is, every project has a limited amount of activities which can be carried out in parallel and the sequential work can not be speeded up by hiring more number of additional developers.

Capers Jones' Estimating Rules of Thumb

- Empirical rules: (IEEE journal – 1996)
  - Formulated based on observations
  - No scientific basis
- Because of their simplicity:
  - These rules are handy to use for making off-hand estimates. Not expected to yield very accurate estimates.
  - Give an insight into many aspects of a project for which no formal methodologies exist yet.

Capers Jones' Rules

Rule 1: SLOC-function point equivalence:

One function point = 125 SLOC for C programs.

Rule 2: Project duration estimation:

Function points raised to the power 0.4 predicts the approximate development time in calendar months.

Rule 3: Rate of requirements creep:

User requirements creep in at an average rate of 2% per month from the design through coding phases.

Illustration:

Size of a project is estimated to be 150 function points.

Rule-1: 150 X 125 = 18,750 SLOC

Rule-2: Development time = $150^{0.4}$ = 7.42 ≈ 8 months

Rule-3: The original requirement will grow by 2% per month i.e 2% of 150 is 3 FPs per month.

- If the duration of requirements specification and testing is 5 months out of total development time of 8 months, the total requirements creep will be roughly 3 X 5 = 15 function points.
- The total size of the project considering the creep will be 150 + 15 = 165 function points and the manager need to plan on 165 function points.

Capers Jones' Rules

Rule 4: Defect removal efficiency:

Each software review, inspection, or test step will find and remove 30% of the bugs that are present. (Companies use a series of defect removal steps like requirement review, code inspection, code walk-through followed by unit, integration and system testing. A series of ten consecutive defect removal operations must be utilized to achieve good product reliability.)

Rule 5: Project manpower estimation:

The size of the software (in function points) divided by 150 predicts the approximate number of personnel required for developing the application. (For a project size of 500 FPs the number of development personnel will be 500/125 = 4, without considering other aspects like use of CASE tools, project complexity and programming languages.)

Capers' Jones Rules

Rule 6: Software development effort estimation:

The approximate number of staff months of effort required to develop a software is given by the software development time multiplied with the number of personnel required. (using rule 2 and 5 the effort estimation for the project size of 150 FPs is 8 X 1 = 8 person-months)

Rule 7: Number of personnel for maintenance

Function points divided by 500 predicts the approximate number of personnel required for regular maintenance activities. (as per Rule-1, 500 function points is equivalent to about 62,500 SLOC of C program, the maintenance personnel would be required to carry out minor fixing, functionality adaptation **ONE**.)

Some conclusions: how to review estimates

Ask the following questions about an estimate

What are the task size drivers?

What productivity rates have been used?

Is there an example of a previous project of about the same size?

Are there examples of where the productivity rates used have actually been found?