Project Management: Estimation

Lecture 17

Importance of Estimations

During the planning phase of a project, a first guess about cost and time is necessary

Estimations are often the basis for the decision to start a project

Estimations are the foundation for project planning and for further actions

→ Estimating is one of the core tasks of project management, but still considered as black magic !

Challenges

Incomplete knowledge about:

- Project scope and changes
- Prospective resources and staffing
- Technical and organizational environment
- Infrastructure
- Feasibility of functional requirements

- Comparability of projects in case of new or changing technologies, staff, methodologies
- Learning curve problem
- Different expectations towards project manager.

Problems with Estimations

Estimation results (effort and time) are almost always too high (for political / human reasons) and have to be adjusted in a structured and careful manner

Reviews by experts always necessary

New technologies can make new parameters necessary

Depending on the situation, multiple methods are to be used in combination.

Guiding Principles

Documentation of assumptions about

- Estimation methodology
- Project scope, staffing, technology

Definition of estimation accuracy

Increasing accuracy with project phases

i.e. Better estimation for implementation phase after object design is finished

Reviews by experienced colleagues

Components of an Estimation

Cost

- Personnel (in person days or valued in personnel cost)
  - Person day: Effort of one person per working day
- Material (PCs, software, tools etc.)
- Extra costs (travel expenses etc.)

Development Time

- Project duration
- Dependencies

Infrastructure

- Rooms, technical infrastructure, especially in offshore scenarios

Estimating Development Time

Development time often estimated by formula

Duration = Effort / People

Problem with formula, because:

- A larger project team increases communication complexity which usually reduces productivity

- Therefore it is not possible to reduce duration arbitrarily by adding more people to a project

Estimating Personnel Cost

Personnel type: Team leader, application domain expert, analyst, designer, programmer, tester…

Cost rate: Cost per person per day

2 alternatives for cost rate:

1. Single cost rate for all types (no differentiation necessary)
2. Assign different cost rates to different personnel types based on experience, qualification and skills

Personnel cost: person days x cost rate.

Estimating Effort

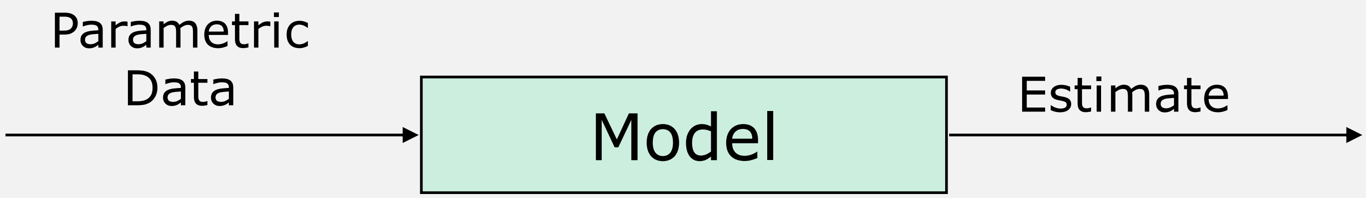
Most difficult part during project planning

Many planning tasks (especially project schedule) depend on determination of effort

Basic principle:

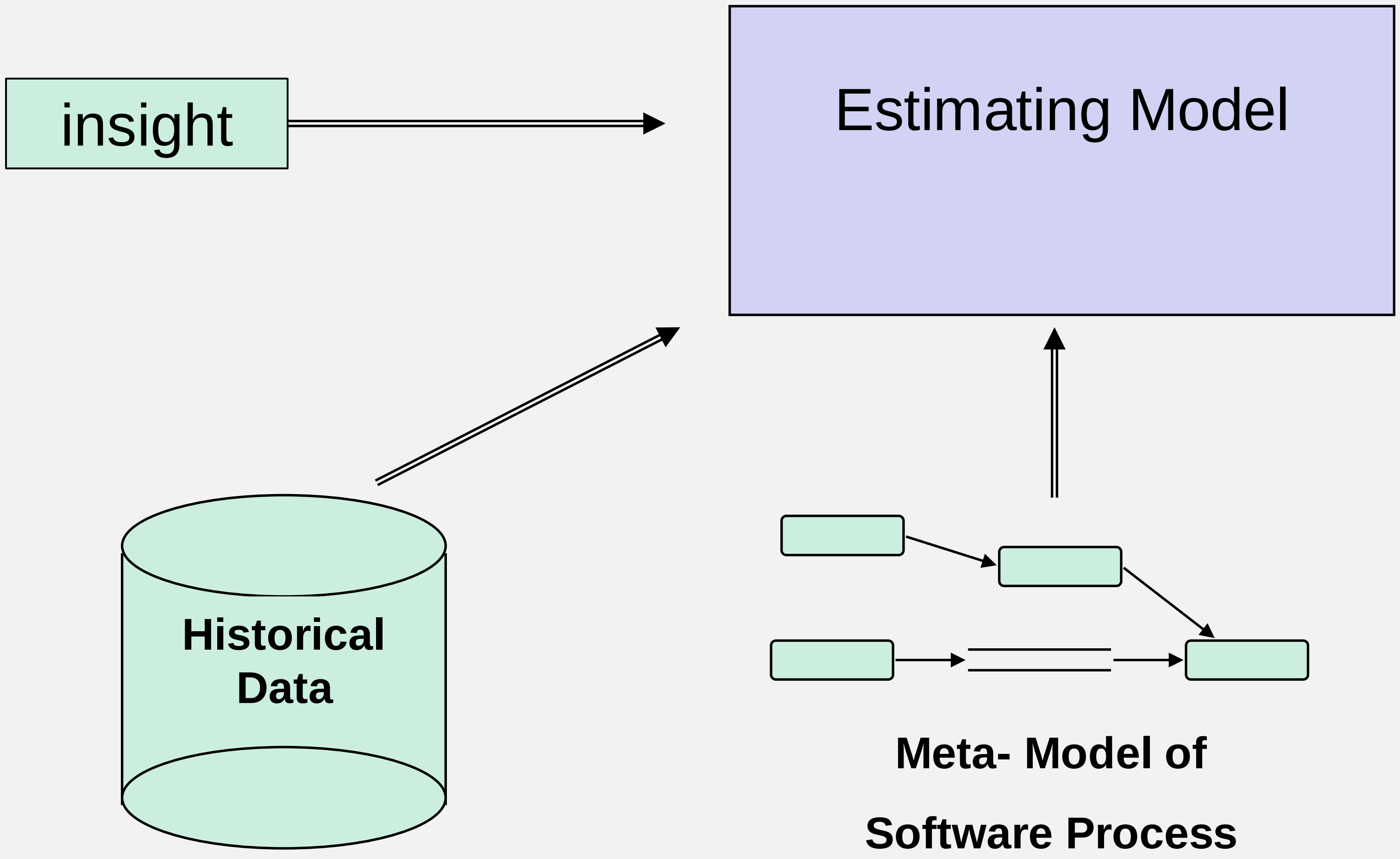
- Select an estimation model (or build one first)
- Evaluate known information: size and project data, resources, software process, system components
- Feed this information as parametric input data into the model
- Model converts the input into estimates: effort, schedule, performance, cycle time.

Basic Use of Estimation Models

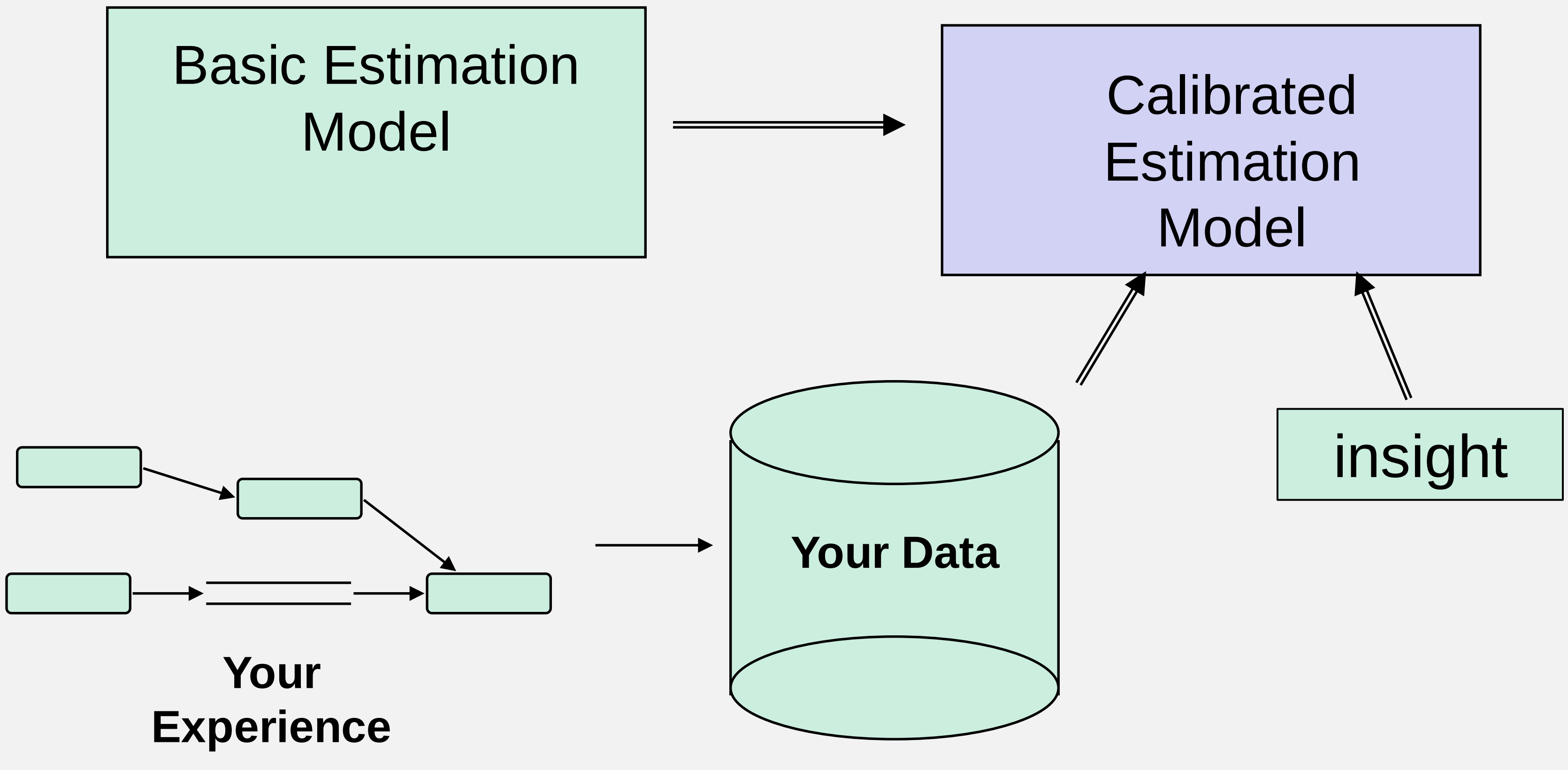


Example	
Data Input	Estimate
Size and Project Data	Effort and schedule
System model	Performance
Software Project	Cycle Time

How do you Build an Estimating Model?



Calibrating an Estimation Model



Top-Down and Bottom-Up Estimation

Two common approaches for estimations

Top-Down Approach

- Estimate effort for the whole project
- Breakdown to different project phases and work products

Bottom-Up Approach

- Start with effort estimates for tasks on the lowest possible level
- Aggregate the estimates until top activities are reached.

Top-Down versus Bottom-Up (cont'd)

Top-Down Approach

- Normally used in the planning phase when little information is available how to solve the problem
- Based on experiences from similar projects
- Not appropriate for project controlling (too high-level)
- Risk add-ons usual

Bottom-Up Approach

- Normally used after activities are broken down the task level and estimates for the tasks are available
- Result can be used for project controlling (detailed level)
- Smaller risk add-ons

Often a mixed approach with recurring estimation cycles is used.

Estimation Techniques

1. Expert estimates
2. Lines of code
3. Function point analysis
4. COCOMO I
5. COCOMO II

Expert Estimates

= Guess from experienced people

- No better than the participants
- Suitable for atypical projects
- Result justification difficult
- Important when no detailed estimation can be done (due to lacking information about scope)

Lines of Code

Traditional way for estimating application size

Advantage: Easy to do

Disadvantages:

- Focus on developer's point of view
- No standard definition for "Line of Code"
- "You get what you measure": If the number of lines of code is the primary measure of productivity, programmers ignore opportunities of reuse
- Multi-language environments: Hard to compare mixed language projects with single language projects

"The use of lines of code metrics for productivity should be regarded as professional malpractice"

Function Point Analysis

Developed by Allen Albrecht, IBM Research, 1979

Technique to determine size of software projects

- Size is measured from a functional point of view
- Estimates are based on functional requirements

Albrecht originally used the technique to predict effort

- Size is usually the primary driver of development effort

Independent of

- Implementation language and technology
- Development methodology
- Capability of the project team

A top-down approach based on function types

Three steps: Plan the count, perform the count, estimate the effort.

Steps in Function Point Analysis

Plan the count

- Type of count: development, enhancement, application
- Identify the counting boundary
- Identify sources for counting information: software, documentation and/or expert

Perform the count

- Count data access functions
- Count transaction functions

Steps in Function Point Analysis

Estimate the effort

- Compute the unadjusted function points (UFP)
- Compute the Value Added Factor (VAF)
- Compute the adjusted Function Points (FA)
- Compute the performance factor
- Calculate the effort in person days

Function Types

Data function types

- # of internal logical files (ILF)
- # of external interface files (EIF)

Transaction function types

- # of external input (EI)
- # of external output (EO)
- # of external queries (EQ)

Calculate the UFP (unadjusted function points):

UFP = a · EI + b · EO + c · EQ + d · ILF + e · EIF

a-f are weight factors

Calculate the Unadjusted Function Points

			Weight Factor				
Type	number	Times	simple	average	complex	equals	UFP
EI		×	3	4	6	=	
EO		×	4	5	7	=	
EQ		×	3	4	6	=	
ILF		×	7	10	15	=	
EIF		×	5	7	10	=	
					Total	=	

14 General System Complexity Factors

The unadjusted function points are adjusted with general system complexity (GSC) factors

Factors	Name	Value
GSC 01	Reliable Backup and Recovery	0 - 5
GSC 02	Use of Data Communication	
GSC 03	Use of Distributed Computing	
GSC 04	Performance	
GSC 05	Realization in heavily used configuration	
GSC 06	Online data entry	
GSC 07	User Friendly	
GSC 08	Online data change	
GSC 09	Complex user interface	
GSC 10	Complex procedure	
GSC 11	Reuse	
GSC 12	Ease of installation	
GSC 13	Use at multiple sites	
GSC 14	Adaptability and flexibility	

Calculate the Effort

After the GSC factors are determined, compute the Value Added Factor (VAF):

$$VAF = 0.65 + 0.01 * \sum_{i=1}^{14} GSC_i \qquad GSC_i = 0,1,...,5$$

FP = UFP*VAF

Performance factor

PF = Number of function points that can be completed per day

Effort = FP / PF

Examples

UFP = 18

Sum of GSC factors = 0.22

VAF = 0.87

Adjusted FP = VAF * UFP = 0.87 * 18 ~ 16

PF =2

Effort = 16/2 = 8 person days

UFP = 18

Sum of GSC factors = 0.70

VAF = 1.35

Adjusted FP = VAF * UFP = 1.35 * 18 ~ 25

PF = 1

Effort = 25/1 = 25 person days

Advantages of Function Point Analysis

Independent of implementation language and technology

Estimates are based on design specification

- Usually known before implementation tasks are known

Users without technical knowledge can be integrated into the estimation process

- Incorporation of experiences from different organizations

Easy to learn

- Limited time effort

Disadvantages of Function Point Analysis

Complete description of functions necessary

- Often not the case in early project stages -> especially in iterative software processes

Only complexity of specification is estimated

- Implementation is often more relevant for estimation

High uncertainty in calculating function points:

- Weight factors are usually deduced from past experiences (environment, used technology and tools may be out-of-date in the current project)

Does not measure the performance of people

COCOMO (COnstructive COst MOdel)

Also called COCOMO I or Basic COCOMO

Top-down approach to estimate cost, effort and schedule of software projects, based on size and complexity of projects

Assumptions:

- Derivability of effort by comparing finished projects ("COCOMO database")
- System requirements do not change during development
- Exclusion of some efforts (for example administration, training, rollout, integration).

Calculation of Effort

Estimate number of instructions

KDSI = "Kilo Delivered Source Instructions"

Determine project complexity parameters: A, B

- Regression analysis, matching project data to equation

3 levels of difficulty that characterize projects

- Simple project (**organic**- well understood, small dev team, experienced team member)
- Semi-complex project (**semidetached**- team with experienced and inexperienced member)
- Complex project (**embedded**- strongly coupled to hardware)

Calculate effort

$$\textbf{Effort} = A * KDSI^{B}$$

Also called Basic COCOMO

Calculation of Effort in Basic COCOMO

Formula: $Effort = A * KDSI^B$

Effort is counted in person months: 152 productive hours (8 hours per day, 19 days/month, less weekends, holidays, etc.)

A, B are constants based on the complexity of the project

Project Complexity	A	B
Simple	2.4	1.05
Semi Complex	3.0	1.12
Complex	3.6	1.20

Calculation of Development Time

Basic formula: $T = C * Effort^D$

T = Time to develop in months

C, D = constants based on the complexity of the project

Effort = Effort in person months

Project Complexity	**C**	**D**
Simple	2.5	0.38
Semi Complex	2.5	0.35
Complex	2.5	0.32

Basic COCOMO Example

Volume = 30000 LOC = 30KLOC

Project type = Simple

Effort = $2.4 * (30)^{1.05}$ = 85 PM

Development Time = $2.5 * (85)^{0.38}$ = 13.5 months

=> Avg. staffing: 85/13.5 = 6.3 persons

=> Avg. productivity: 30000/85 = 353 LOC/PM

Compare:	Semi-detached:	135 PM	13.9 M	9.7 persons
	Embedded:	213 PM	13.9 M	15.3 persons

Other COCOMO Models

Intermediate COCOMO

- 15 cost drivers yielding a multiplicative correction factor
- Basic COCOMO is based on value of 1.00 for each of the cost drivers

Detailed COCOMO

- Multipliers depend on phase: Requirements; System Design; Detailed Design; Code and Unit Test; Integrate & Test; Maintenance

Steps in Intermediate COCOMO

Basic COCOMO steps:

- Estimate number of instructions
- Determine project complexity parameters: A, B
- Determine level of difficulty that characterizes the project

New step:

- Determine cost drivers
  - 15 cost drivers c1 , c1 …. c15

Calculate effort

- Effort = A * KDSI^B * c1 * c1 …. * c15

Calculation of Effort in Intermediate COCOMO

Basic formula:

$\text{Effort} = A * \text{KDSI}^B * c_1 * c_1 \ldots .* c_{15}$

Effort is measured in PM (person months, 152 productive hours (8 hours per day, 19 days/month, less weekends, holidays, etc.)

A, B are constants based on the complexity of the project

Project Complexity	A	B
Simple	2.4	1.05
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Intermediate COCOMO: 15 Cost drivers

Factors	Name	Value
01	Required Reliability	Very low, low, nominal, high, very high, extra high
02	Database Size	
03	Product Complexity	
04	Execution time constraint	
05	Main Storage Constraint	
06	Virtual storage volatility	
07	Turnaround time	
08	Analyst capability	
09	Applications experience	
10	Programmer capability	
11	Virtual machine experience	
12	Language Experience	
13	Use of Modern programming language	
14	Use of software tools	
15	Required development tools	

COCOMO II

Revision of COCOMO I in 1997

Provides three models of increasing detail

Application Composition Model

- Estimates for prototypes based on GUI builder tools and existing components

Early Design Model

- Estimates before software architecture is defined
- For system design phase, closest to original COCOMO, uses function points as size estimation

Post Architecture Model

- Estimates after architecture is defined
- For actual development phase and maintenance; Uses FPs or SLOC as size measure

Estimator selects one of the three models based on current state of the project.

COCOMO II (cont'd)

Targeted for iterative software lifecycle models

Boehm's spiral model

COCOMO I assumed a waterfall model

30% design; 30% coding; 40% integration and test

COCOMO II includes new costs drivers to deal with

- Team experience
- Developer skills
- Distributed development

COCOMO II includes new equations for reuse

Enables build vs. buy trade-offs

COCOMO II: Added Cost drivers

- Development flexibility
- Team cohesion
- Developed for reuse
- Precedent
- Architecture & risk resolution
- Personnel continuity
- Documentation match life cycle needs
- Multi-Site development.

Advantages of COCOMO

Appropriate for a quick, high-level estimation of project costs

Fair results with smaller projects in a well known development environment

- Assumes comparison with past projects is possible

Covers all development activities (from analysis to testing)

Intermediate COCOMO yields good results for projects on which the model is based

Problems with COCOMO

Judgment requirement to determine the influencing factors and their values

Experience shows that estimation results can deviate from actual effort by a factor of 4

Some important factors are not considered:

- Skills of team members, travel, environmental factors, user interface quality, overhead cost

Thank You