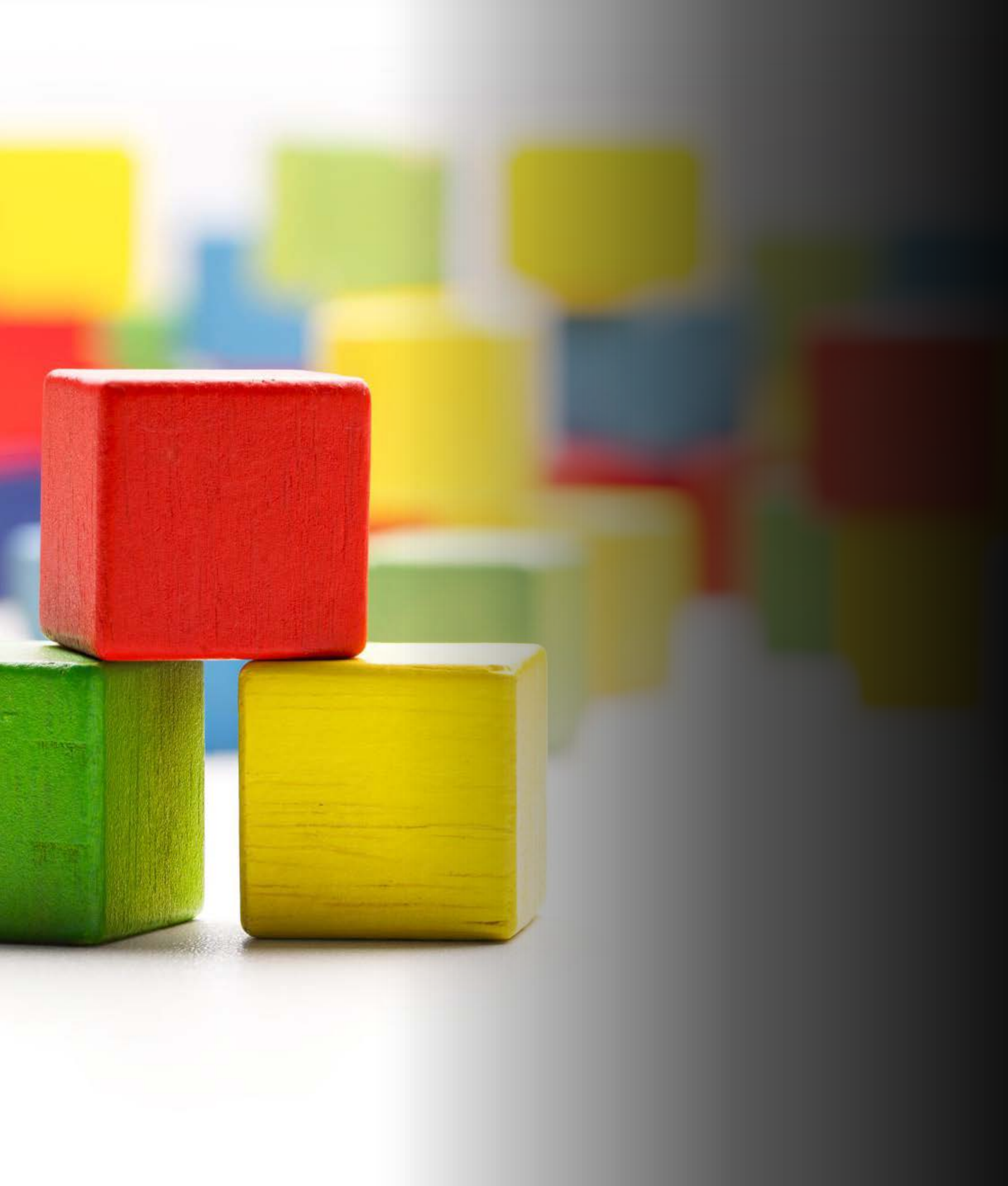

Software Engineering

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Contents of the slides are prepared based on the materials from web and textbooks. It is stated that this material will be used to make the students aware of the topics and practiced for non-profit purposes.

(slide can be found in this secure domain)

Software project Management

Contents...

Introduction

Many software projects fail:

due to faulty project management practices:

- It is important to learn different aspects of software project management.

Goal of software project management:

enable a group of engineers to work efficiently towards successful completion of a software project.

Responsibility of project managers

- Project proposal writing
- Project cost estimation
- Scheduling
- Project staffing
- Project monitoring and control
- Software configuration management
- Risk management
- Managerial report writing and presentations, etc.

Introduction [CONTD.]

A project manager's activities are varied.

can be broadly classified into:

- project planning,
- project monitoring and control activities.

Once a project is found to be feasible,

project managers undertake project planning.

Project Planning Activities

Estimation:	Effort, cost, resource, and project duration
Project scheduling:	
Staff organization:	staffing plans
Risk handling:	identification, analysis, and abatement procedures
Miscellaneous plans:	quality assurance plan, configuration management plan, etc.

Project planning

- Requires utmost care and attention --- commitments to unrealistic time and resource estimates result in:
  - ✓ irritating delays.
  - ✓ customer dissatisfaction
  - ✓ adverse affect on team morale
    - ❑ Poor quality work
  - ✓ project failure.

Sliding Window Planning

- Involves project planning over several stages:
  - ✓ protects managers from making big commitments too early.
  - ✓ More information becomes available as project progresses.
    - ❑ Facilitates accurate planning

SPMP Document

- After planning is complete:
  - ✓ Document the plans:
  - ✓ in a Software Project Management Plan(SPMP) document.

Organization of SPMP Document

Introduction (Objectives, Major Functions, Performance Issues, Management and Technical Constraints)

Project Estimates (Historical Data, Estimation Techniques, Effort, Cost, and Project Duration Estimates)

Project Resources Plan (People, Hardware and Software, Special Resources)

Schedules (Work Breakdown Structure, Task Network, Gantt Chart Representation, PERT Chart Representation)

Risk Management Plan (Risk Analysis, Risk Identification, Risk Estimation, Abatement Procedures)

Project Tracking and Control Plan

Miscellaneous Plans (Process Tailoring, Quality Assurance)

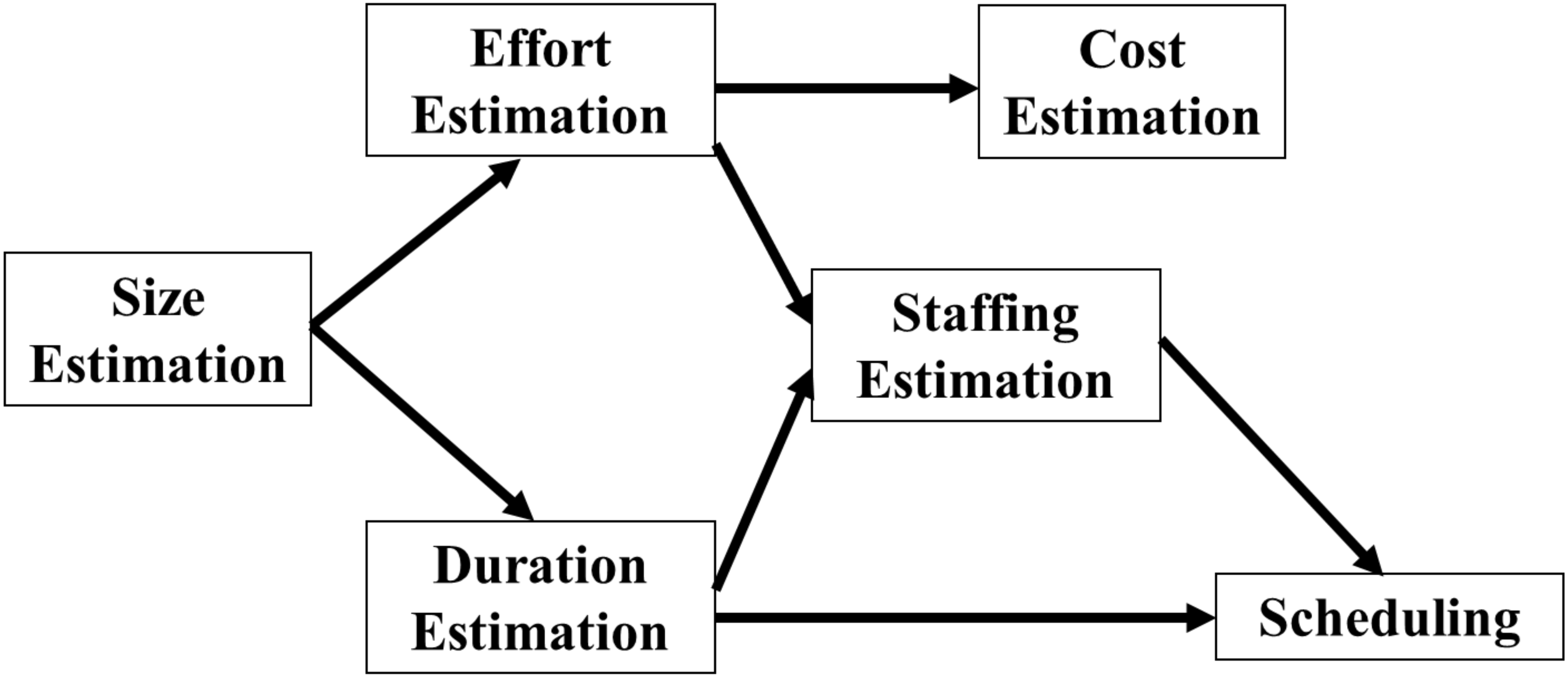
Software Cost Estimation

Determine — Determine **size** of the product.

Estimate — From the size estimate,
- determine the **effort** needed.

Estimate — From the effort estimate,
- determine **project duration, and cost.**

Software Cost Estimation



Software Cost Estimation

- Three main approaches to estimation:
  - ✓ Empirical
  - ✓ Heuristic
  - ✓ Analytical

Software Cost Estimation Techniques

Empirical techniques	an educated guess based on past experience.
Heuristic techniques	assume that the characteristics to be estimated can be expressed in terms of some mathematical expression.
Analytical techniques	derive the required results starting from certain simple assumptions.

Software Size Metrics

LOC (Lines of Code):

- Simplest and most widely used metric.
- Comments and blank lines should not be counted.

Disadvantages of Using LOC

- Size can vary with coding style.
- Focuses on coding activity alone.
- Correlates poorly with quality and efficiency of code.
- Penalizes higher level programming languages, code reuse, etc.

Software Size Metrics

Disadvantages of Using LOC

- Measures lexical/textual complexity only.
- does not address the issues of structural or logical complexity.
- Difficult to estimate LOC from problem description.
- So not useful for project planning

Function Point Metric

Overcomes some of the shortcomings of the LOC metric

Proposed by Albrecht in early 80's:

FP=4 #inputs + 5 #Outputs + 4 #inquiries + 10 #files + 10 #interfaces

Input:

A set of related inputs is counted as one input.

Function Point Metric

Output:	A set of related outputs is counted as one output.
Inquiries:	Each user query type is counted.
Files:	Files are logically related data and thus can be data structures or physical files.
Interface:	Data transfer to other systems.

Function Point Metric

Suffers from a major drawback:

the size of a function is independent of its complexity.

Extend function point metric:

Feature Point metric:

considers an extra parameter:

- Algorithm Complexity.

Function Point Metric

Proponents claim:

FP is language independent.

Size can be easily derived from problem description

Opponents claim:

it is subjective --- Different people can produce different estimates for the same problem.

Empirical Size Estimation Techniques

Expert Judgement:

-A euphemism for guess made by an expert.

-Suffers from individual bias.

Delphi Estimation:

-overcomes some of the problems of expert judgement.

Expert judgement

Experts divide a software product into component units:

e.g. GUI, database module, data communication module, billing module, etc.

Add up the guesses for each of the components.

Delphi Estimation

Team of Experts and a coordinator.

Experts carry out estimation independently:

- mention the rationale behind their estimation.
- coordinator notes down any extraordinary rationale:
  - ✓circulates among experts.

Experts re-estimate.

Experts never meet each other

- to discuss their viewpoints.

Heuristic Estimation Techniques

Single Variable Model

- Parameter to be Estimated=C_1(Estimated Characteristic)^{d_1}

Multivariable Model

- Assumes that the parameter to be estimated depends on more than one characteristic.
- Parameter to be Estimated=C_1(Estimated Characteristic)^{d_1}+ C_2(Estimated Characteristic)^{d_2}+…
- Usually more accurate than single variable models.

COCOMO Model

- COCOMO (COnstructive COst MOdel) proposed by Boehm.
- Divides software product developments into 3 categories:
  - ✓ Organic
  - ✓ Semidetached
  - ✓ Embedded
- Roughly correspond to:
  - ✓ application, utility and system programs respectively.
    - ❑ Data processing and scientific programs are considered to be application programs.
    - ❑ Compilers, linkers, editors, etc., are utility programs.
    - ❑ Operating systems and real-time system programs, etc. are system programs.

Elaboration of Product classes

Organic	Semidetached	Embedded
Relatively small groups • working to develop well-understood applications.	Project team consists of a mixture of experienced and inexperienced staff.	The software is strongly coupled to complex hardware, or real-time systems.

COCOMO Model (CONT.)

For each of the three product categories:

- From size estimation (in KLOC), Boehm provides equations to predict:
  - ✓project duration in months
  - ✓effort in programmer-months

Boehm obtained these equations:

- examined historical data collected from many actual projects.

COCOMO Model (CONT.)

- Software cost estimation is done through three stages:
  - ✓ Basic COCOMO,
  - ✓ Intermediate COCOMO,
  - ✓ Complete COCOMO.

COCOMO Model (CONT.)

- Gives only an approximate estimation:
  - ✓ Effort = a1 $(KLOC)^{a2}$
  - ✓ Tdev = b1 $(Effort)^{b2}$
    - ❑ KLOC is the estimated kilo lines of source code,
    - ❑ a1,a2,b1,b2 are constants for different categories of software products,
    - ❑ Tdev is the estimated time to develop the software in months,
    - ❑ Effort estimation is obtained in terms of person months (PMs).

Development Effort Estimation

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

Development Time Estimation

Organic:

- $Tdev = 2.5\ (Effort)^{0.38}$ Months

Semi-detached:

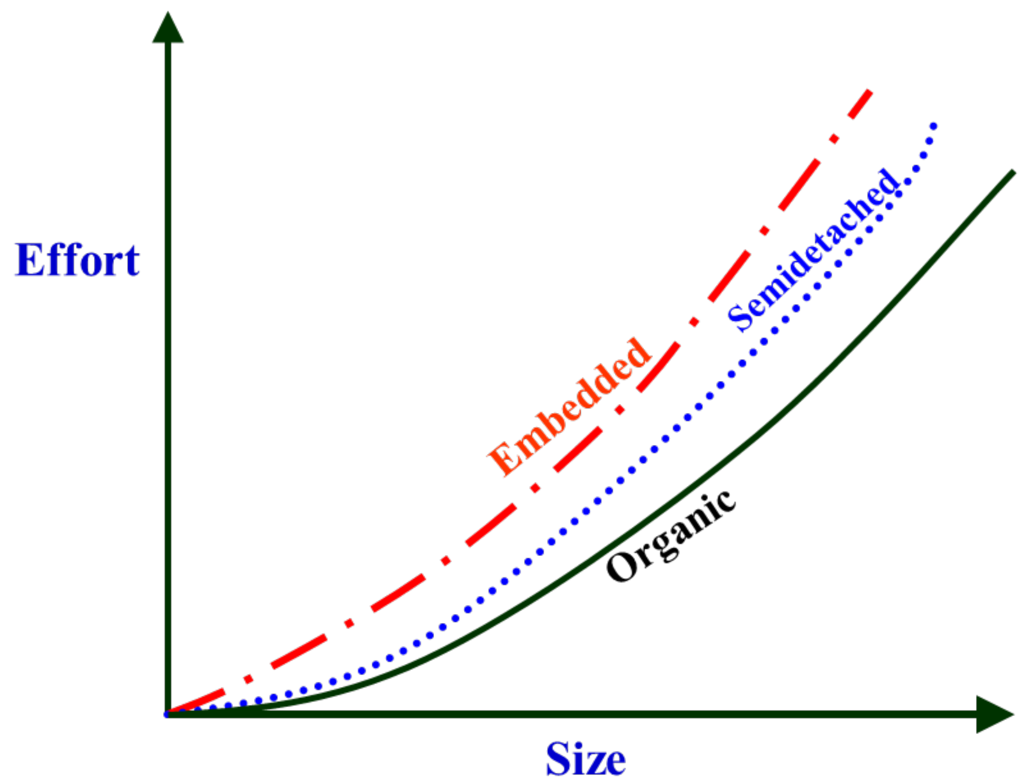
- $Tdev = 2.5\ (Effort)^{0.35}$ Months

Embedded:

- $Tdev = 2.5\ (Effort)^{0.32}$ Months

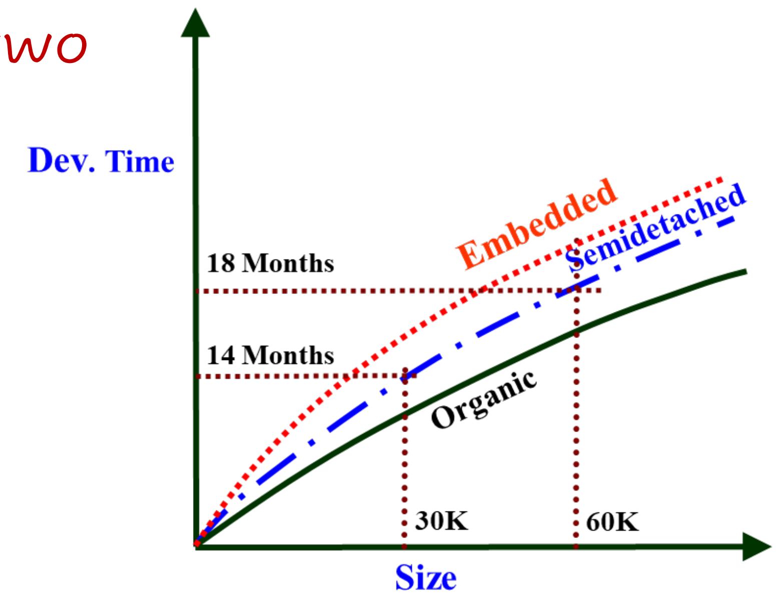
COCOMO Model (CONT.)

- Effort is somewhat super-linear in problem size.



COCOMO Model (CONT.)

- Development time
  - ✓ sublinear function of product size.
- When product size increases two times,
  - ✓ development time does not double.
- Time taken:
  - ✓ almost same for all the three product categories.



COCOMO Model (CONT.)

- Development time does not increase linearly with product size:
  - ✓ For larger products more parallel activities can be identified:
    - ❑ can be carried out simultaneously by a number of engineers.
- Development time is roughly the same for all the three categories of products:
  - ✓ For example, a 60 KLOC program can be developed in approximately 18 months
    - ❑ regardless of whether it is of organic, semi-detached, or embedded type.
  - ✓ There is more scope for parallel activities for system and application programs than utility programs.

Example

- **The size of an organic software product has been estimated to be 32,000 lines of source code.**

- Effort = $2.4*(32)^{1.05}$ = 91 PM

- Nominal development time = $2.5*(91)^{0.38}$ = 14 months

Intermediate COCOMO

Basic COCOMO model assumes

- effort and development time depend on product size alone.

→

However, several parameters affect effort and development time:

- Reliability requirements
- Availability of CASE tools and modern facilities to the developers
- Size of data to be handled

Intermediate COCOMO

- For accurate estimation,
  - ✓ the effect of all relevant parameters must be considered:
  - ✓ Intermediate COCOMO model recognizes this fact:
    - ❑ refines the initial estimate obtained by the basic COCOMO by using a set of 15 cost drivers (multipliers).
  - ✓ If modern programming practices are used,
    - ❑ initial estimates are scaled downwards.
  - ✓ If there are stringent reliability requirements on the product :
    - ❑ initial estimate is scaled upwards.

Intermediate COCOMO

Rate different parameters on a scale of one to three:

Depending on these ratings,

- multiply cost driver values with the estimate obtained using the basic COCOMO.

Cost driver classes:

Product: Inherent complexity of the product, reliability requirements of the product, etc.

Computer: Execution time, storage requirements, etc.

Personnel: Experience of personnel, etc.

Development Environment: Sophistication of the tools used for software development.

Shortcoming of basic and intermediate COCOMO models

- Both models:
  - ✓ consider a software product as a single homogeneous entity:
  - ✓ However, most large systems are made up of several smaller sub-systems.
    - ❑ Some sub-systems may be considered as organic type, some may be considered embedded, etc.
    - ❑ for some the reliability requirements may be high, and so on.

Complete COCOMO

Cost of each sub-system is estimated separately.

Costs of the sub-systems are added to obtain total cost.

Reduces the margin of error in the final estimate.

Complete COCOMO Example

A Management Information System (MIS) for an organization having offices at several places across the country:

- Database part (semi-detached)
- Graphical User Interface (GUI) part (organic)
- Communication part (embedded)

Costs of the components are estimated separately:

- summed up to give the overall cost of the system.

Halstead's Software Science

An analytical technique to estimate:

- size,
- development effort,
- development time.

Halstead used a few primitive program parameters

- number of operators and operands

Halstead's Software Science

- Derived expressions for:
  - ✓ over all program length,
  - ✓ potential minimum volume
  - ✓ actual volume,
  - ✓ language level,
  - ✓ effort, and
  - ✓ development time

Staffing Level Estimation

Number of personnel required during any development project:

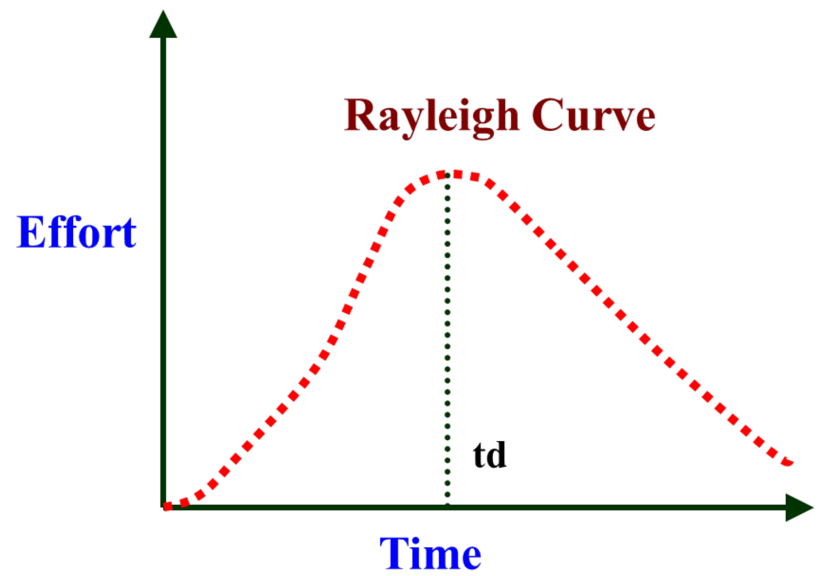
not constant.

Norden in 1958 analysed many R&D projects, and observed:

Rayleigh curve represents the number of full-time personnel required at any time.

Rayleigh Curve

- Rayleigh curve is specified by two parameters:
  - ✓ td the time at which the curve reaches its maximum
  - ✓ K the total area under the curve.
- L=f(K, td)



Putnam's Work:

In 1976, Putnam studied the problem of staffing of software projects:

observed that the level of effort required in software development efforts has a similar envelope.

found that the Rayleigh-Norden curve

- relates the number of delivered lines of code to effort and development time.

Putnam analyzed many army projects, and derived the expression:

$$L = Ck \cdot K^{1/3} \cdot td^{4/3}$$

K is the effort expended and L is the size in KLOC.

td is the time to develop the software.

Ck is the state of technology constant

- reflects factors that affect programmer productivity.

Putnam's Work:

Ck=2 for poor development environment

no methodology, poor documentation, and review, etc.

Ck=8 for good software development environment

software engineering principles used

Ck=11 for an excellent environment

Rayleigh Curve

Very small number of engineers are needed at the beginning of a project

-carry out planning and specification.

As the project progresses:

-more detailed work is required,

-number of engineers slowly increases and reaches a peak.

Putnam observed that:

-the time at which the Rayleigh curve reaches its maximum value

- corresponds to system testing and product release.

Rayleigh Curve

After system testing,

- the number of project staff falls till product installation and delivery.

From the Rayleigh curve observe that:

- approximately 40% of the area under the Rayleigh curve is to the left of td
- and 60% to the right.

Effect of Schedule Change on Cost

- Using the Putnam's expression for L,

$$K = {}^{L^3}\!/_{Ck^3 \cdot td^4}$$

$$\text{Or, } K = C1/td^4$$

- For the same product size, $C1 = L^3/Ck^3$ is a constant.

- Or, $K1/K2 = td2^4/td1^4$

- Observe:
  - ✓ a relatively small compression in delivery schedule
    - ❑ can result in substantial penalty on human effort.

- Also, observe:
  - ✓ benefits can be gained by using fewer people over a somewhat longer time span.

Example

- If the estimated development time is 1 year, then in order to develop the product in 6 months,
  - ✓ the total effort and hence the cost increases 16 times.
  - ✓ In other words,
    - ❑ the relationship between effort and the chronological delivery time is highly nonlinear.

Effect of Schedule Change on Cost
(CONT.)

Putnam model indicates extreme penalty for schedule compression

and extreme reward for expanding the schedule.

Putnam estimation model works reasonably well for very large systems,

but seriously overestimates the effort for medium and small systems.

Effect of Schedule Change on Cost
(CONT.)

Boehm observed:

- "There is a limit beyond which the schedule of a software project cannot be reduced by buying any more personnel or equipment."
- This limit occurs roughly at 75% of the nominal time estimate.

If a project manager accepts a customer demand to compress the development time by more than 25%

- very unlikely to succeed.
  - ✓every project has only a limited amount of parallel activities
  - ✓sequential activities cannot be speeded up by hiring any number of additional engineers.
  - ✓many engineers must sit idle.

Jensen Model

- Jensen model is very similar to Putnam model.
  - ✓ attempts to soften the effect of schedule compression on effort
  - ✓ makes it applicable to smaller and medium sized projects.

- Jensen proposed the equation:
  - ✓ $L = Cte \cdot td \cdot K^{1/2}$
  - ✓ Where,
    - ❑ Cte is the effective technology constant,
    - ❑ td is the time to develop the software, and
    - ❑ K is the effort needed to develop the software.

Organization Structure

- Functional Organization:
  - ✓ Engineers are organized into functional groups, e.g.
    - ❑ specification, design, coding, testing, maintenance, etc.
  - ✓ Engineers from functional groups get assigned to different projects

Advantages of Functional Organization

- Specialization
- Ease of staffing
- Good documentation is produced
  - different phases are carried out by different teams of engineers.
- Helps identify errors earlier.

Project Organization

Engineers get assigned to a project for the entire duration of the project

Same set of engineers carry out all the phases

Advantages:

Engineers save time on learning details of every project.	Leads to job rotation

Team Structure

- Problems of different complexities and sizes require different team structures:
  - ✓ Chief-programmer team
  - ✓ Democratic team
  - ✓ Mixed organization

Democratic Teams

Suitable for:

- small projects requiring less than five or six engineers
- research-oriented projects

A manager provides administrative leadership:

- at different times different members of the group provide technical leadership.

Democratic organization provides

- higher morale and job satisfaction to the engineers
- therefore leads to less employee turnover.

Suitable for less understood problems,

- a group of engineers can invent better solutions than a single individual.

Democratic Teams

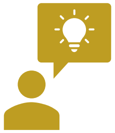
- Disadvantage:
  - ✓ team members may waste a lot time arguing about trivial points:
  - ✓ absence of any authority in the team.

Chief Programmer Team

A senior engineer provides technical leadership:

partitions the task among the team members.

verifies and integrates the products developed by the members.



It works well when

the task is well understood

- also within the intellectual grasp of a single individual,

importance of early completion outweighs other factors

- team morale, personal development, etc.

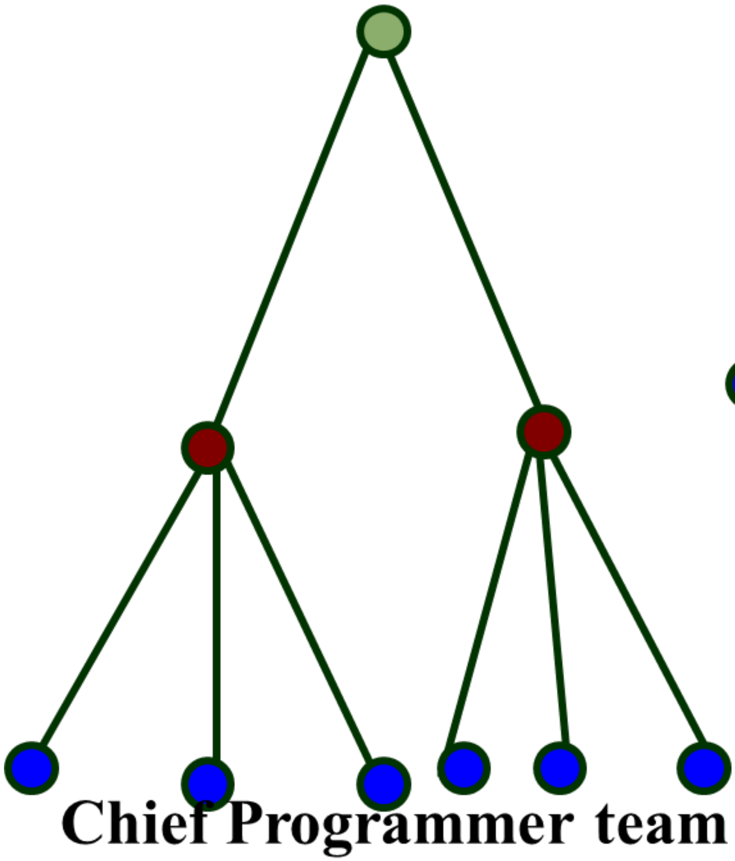
Chief programmer team is subject to single point failure:

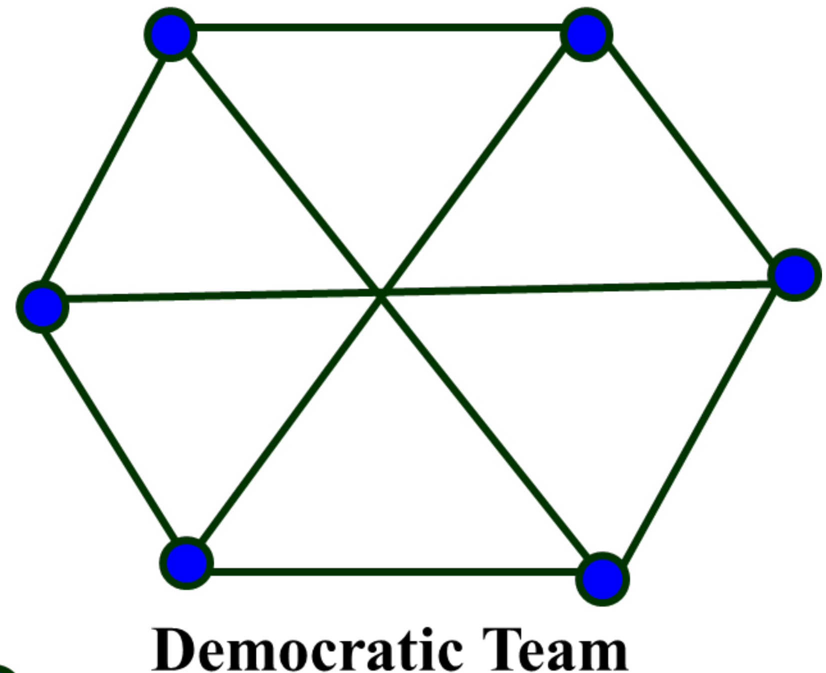
too much responsibility and authority is assigned to the chief programmer.

Mixed Control Team Organization

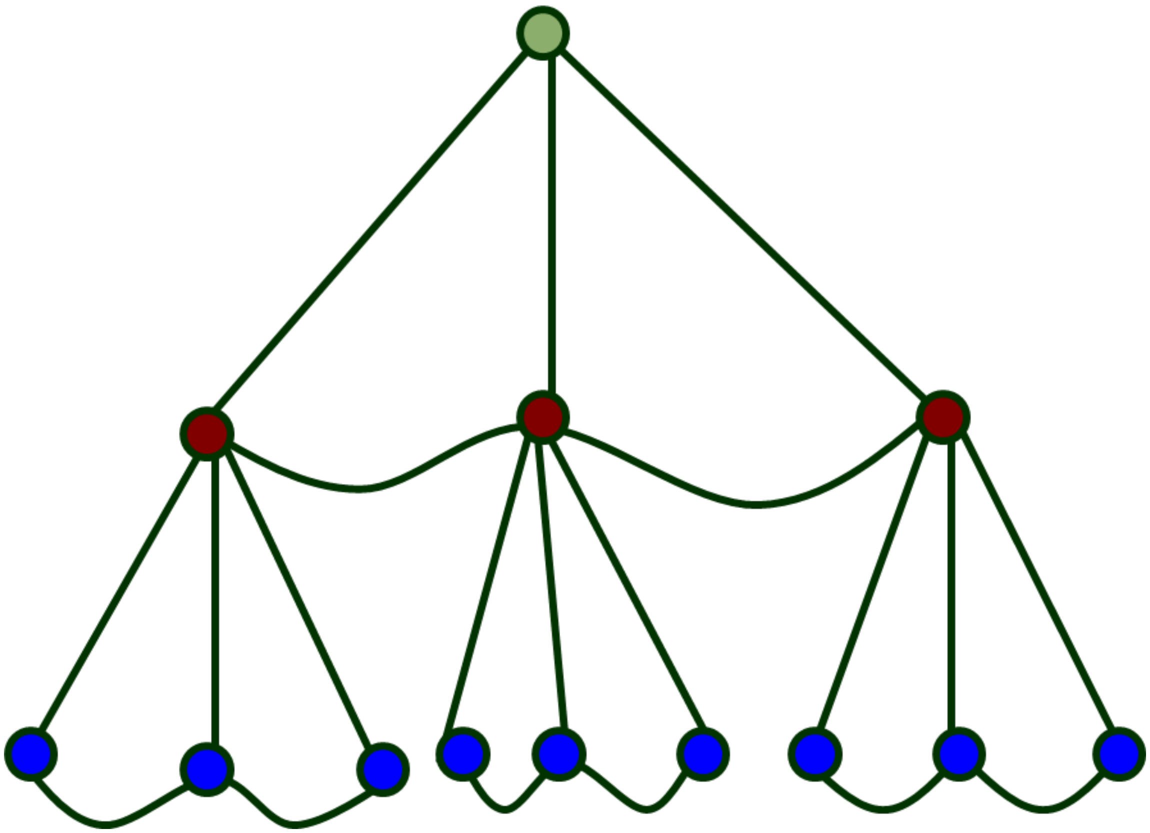
- Draws upon ideas from both:
  - ✓ democratic organization and
  - ✓ chief-programmer team organization.
- Communication is limited
  - ✓ to a small group that is most likely to benefit from it.
- Suitable for large organizations.

Team Organization





Mixed team organization



Summary

- We discussed the broad responsibilities of the project manager:
  - ✓ Project planning
  - ✓ Project Monitoring and Control
- To estimate software cost:
  - ✓ Determine size of the product.
  - ✓ Using size estimate,
    - ❑ determine effort needed.
  - ✓ From the effort estimate,
    - ❑ determine project duration, and cost.

Summary

- Cost estimation techniques:
  - ✓ Empirical Techniques
  - ✓ Heuristic Techniques
  - ✓ Analytical Techniques
- Empirical techniques:
  - ✓ based on systematic guesses by experts.
  - ✓ Expert Judgement
  - ✓ Delphi Estimation
- Heuristic techniques:
  - ✓ assume that characteristics of a software product can be modelled by a mathematical expression.
  - ✓ COCOMO

Summary

- Analytical techniques:
  - ✓ derive the estimates starting with some basic assumptions:
  - ✓ Halstead's Software Science
- The staffing level during the life cycle of a software product development:
  - ✓ follows Rayleigh curve
  - ✓ maximum number of engineers required during testing.

Summary

- Relationship between schedule change and effort:
  - ✓ highly nonlinear.
- Software organizations are usually organized in:
  - ✓ functional format
  - ✓ project format
- Project teams can be organized in following ways:
  - ✓ Chief programmer: suitable for routine work.
  - ✓ Democratic: Small teams doing R&D type work
  - ✓ Mixed: Large projects