Software Project Management

Organization of this Lecture:

- Introduction to Project Planning
- Software Cost Estimation
  - Cost Estimation Models
  - Software Size Metrics
  - Empirical Estimation
  - Heuristic Estimation
  - COCOMO
- Staffing Level Estimation
- Effect of Schedule Compression on Cost
- Summary

Introduction

- Many software projects fail:
  - due to faulty project management practices:
    - It is important to learn different aspects of software project management.

Introduction

- 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

- A project manager's activities are varied.
  - can be broadly classified into:
    - project planning,
    - project monitoring and control activities.

Project Planning

- 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.

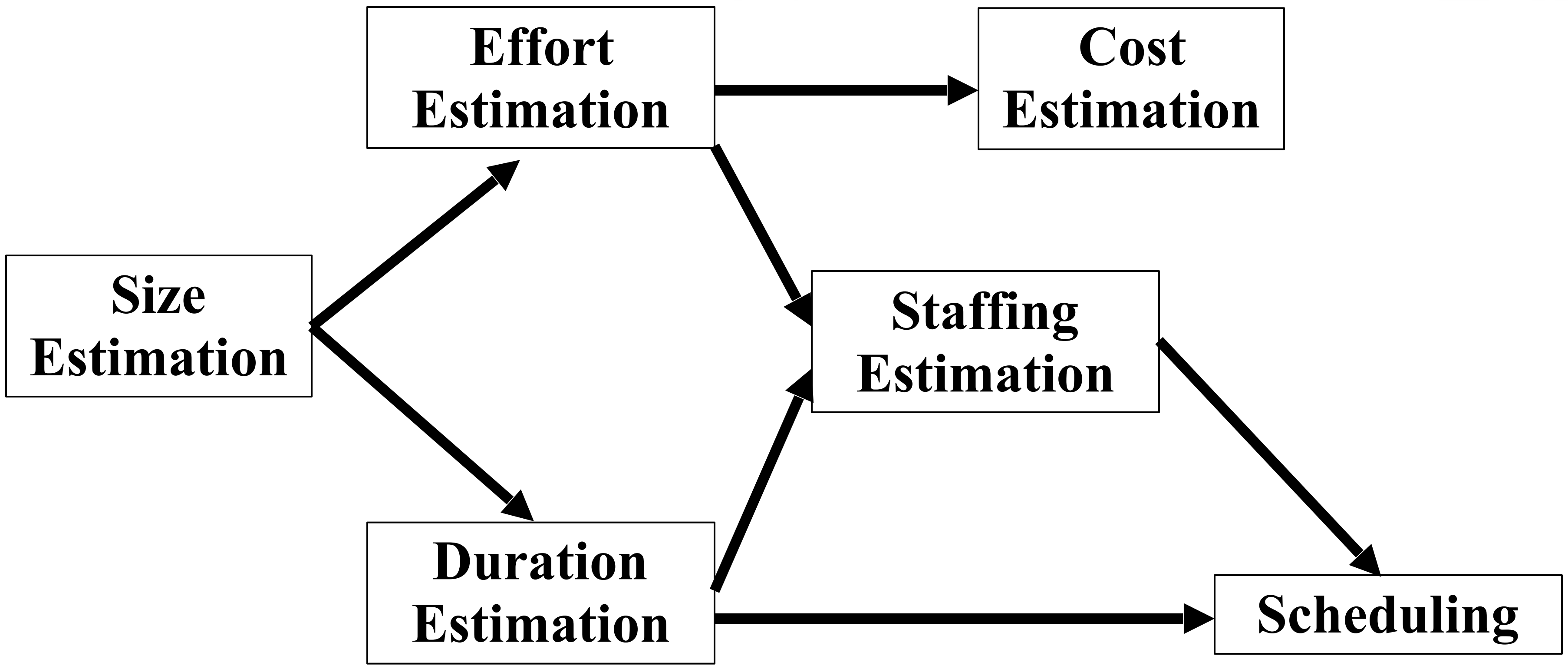
Organization of SPMP Document

- 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 size of the product.
- From the size estimate,
  - determine the effort needed.
- 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.

Disadvantages of Using LOC (cont...)

- 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 (CONT.)

- Suffers from a major drawback:
  - the size of a function is considered to be independent of its complexity.
- Extend function point metric:
  - Feature Point metric:
  - considers an extra parameter:
    - Algorithm Complexity.

Function Point Metric (CONT.)

- Proponents claim:
  - FP is language independent.
  - Size can be easily derived from problem description
- Opponents claim:
  - it is subjective --- Different people can come up with different estimates for the same problem.

Empirical Size Estimation Techniques

- Expert Judgement:
  - An 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.

Delphi Estimation:

- Experts re-estimate.
- Experts never meet each other
  - to discuss their viewpoints.

Heuristic Estimation Techniques

- Single Variable Model:
  - Parameter to be Estimated=C1(Estimated Characteristic)d1
- Multivariable Model:
  - Assumes that the parameter to be estimated depends on more than one characteristic.
  - Parameter to be Estimated=C1(Estimated Characteristic)d1+ C2(Estimated Characteristic)d2+…
  - 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

COCOMO Product classes

- 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:
  - Relatively small groups
    - working to develop well-understood applications.
- Semidetached:
  - Project team consists of a mixture of experienced and inexperienced staff.
- Embedded:
  - 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 a large number of actual projects.

COCOMO Model (CONT.)

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

Basic 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

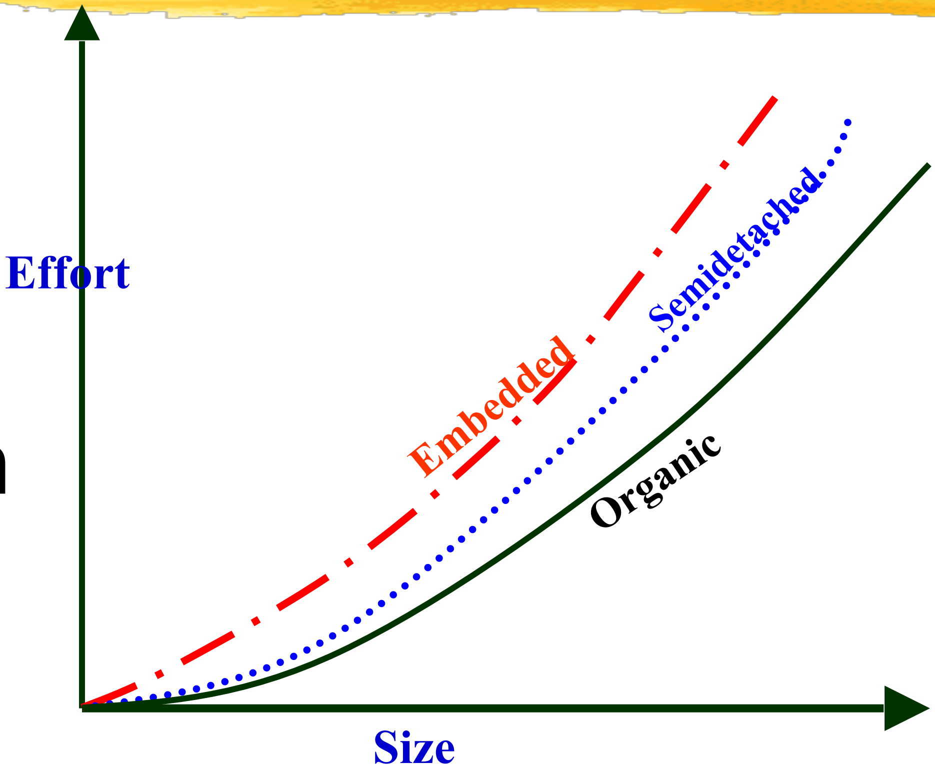
- Organic :
  - Effort = 2.4 (KLOC)1.05 PM
- Semi-detached:
  - Effort = 3.0(KLOC)1.12 PM
- Embedded:
  - Effort = 3.6 (KLOC)1.20PM

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

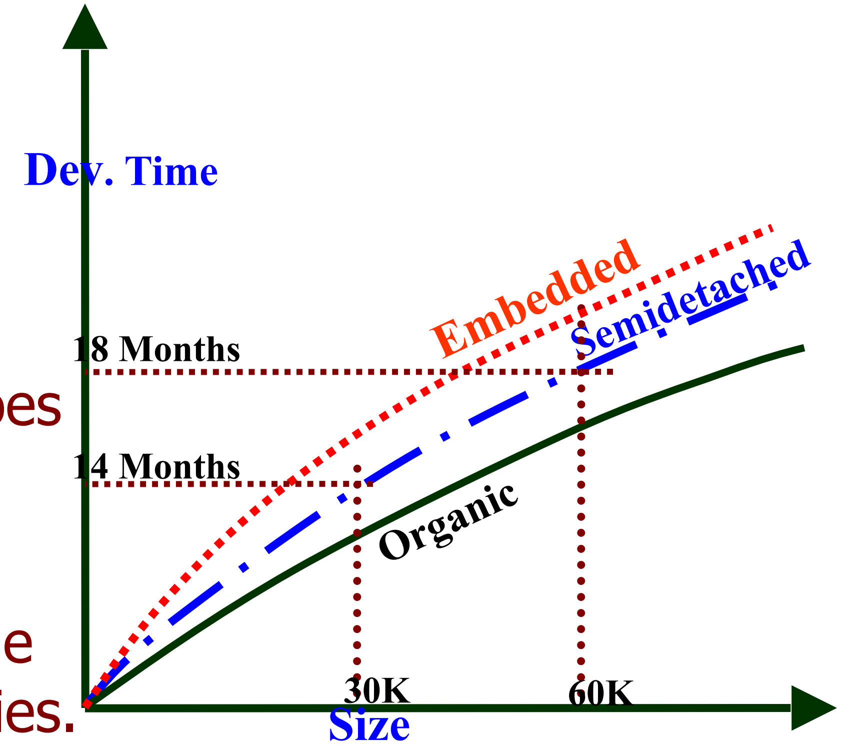
Basic COCOMO Model (CONT.)

- Effort is somewhat super-linear in problem size.



Basic 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.



Basic 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.

Basic COCOMO Model (CONT.)

- 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).

Intermediate COCOMO (CONT.)

- 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 (CONT.)

- 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.

Intermediate COCOMO (CONT.)

- 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's Software Science

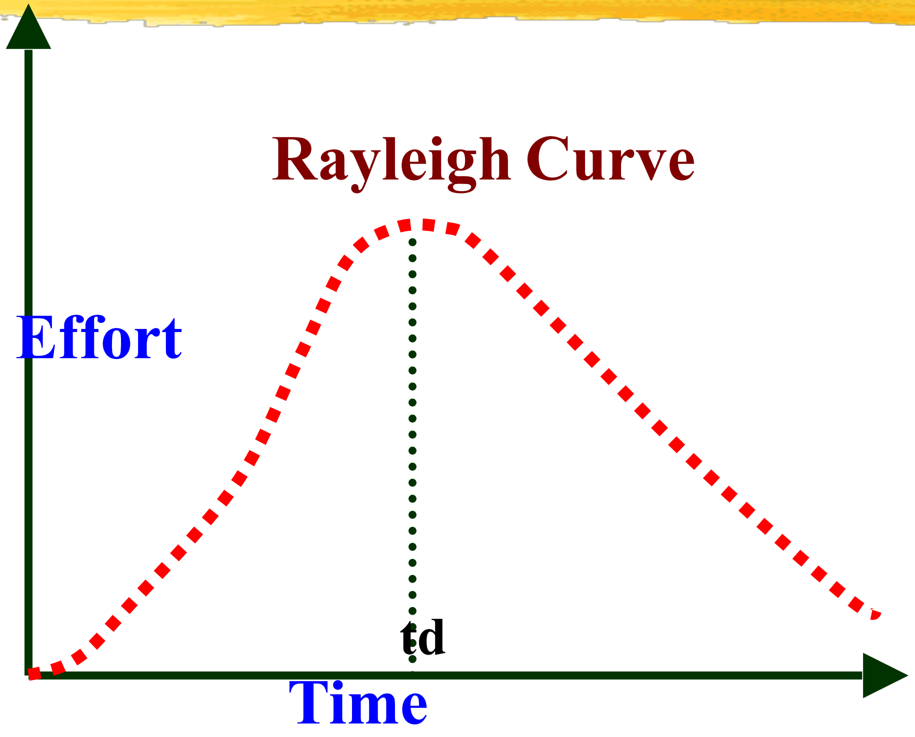
- Halstead used a few primitive program parameters
  - number of operators and operands
- Derived expressions for:
  - over all program length,
  - potential minimum volume
  - actual volume,
  - language level,
  - effort, and
  - development time.

Staffing Level Estimation

- Number of personnel required during any development project:
  - not constant.
- Norden in 1958 analyzed 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's Work (CONT.):

- Putnam analyzed a large number of army projects, and derived the expression:

  L=CkK1/3td4/3

  - 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 (CONT.):

- 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.

Rayleigh Curve

- Putnam observed that:
  - the time at which the Rayleigh curve reaches its maximum value
    - corresponds to system testing and product release.
  - After system testing,
    - the number of project staff falls till product installation and delivery.

Rayleigh Curve

- 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=L3/Ck3td4

  Or, K=C1/td4
- For the same product size, C1=L3/Ck3 is a constant.
- Or, K1/K2 = td24/td14

Effect of Schedule Change on Cost (CONT.)

- 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.

Effect of Schedule Change on Cost (CONT.)

- 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 have to 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 Model

- Jensen proposed the equation:
  - $L=CtetdK1/2$
  - 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 Teams

- 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.

Chief Programmer Team

- 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.

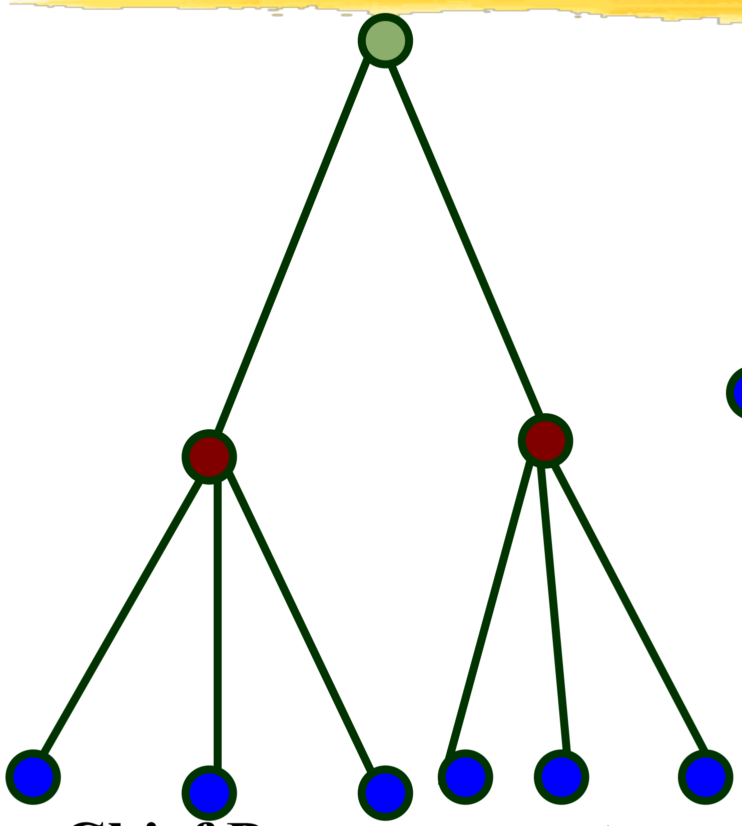
Chief Programmer Team

- Chief programmer team is subject to single point failure:
  - too much responsibility and authority is assigned to the chief programmer.

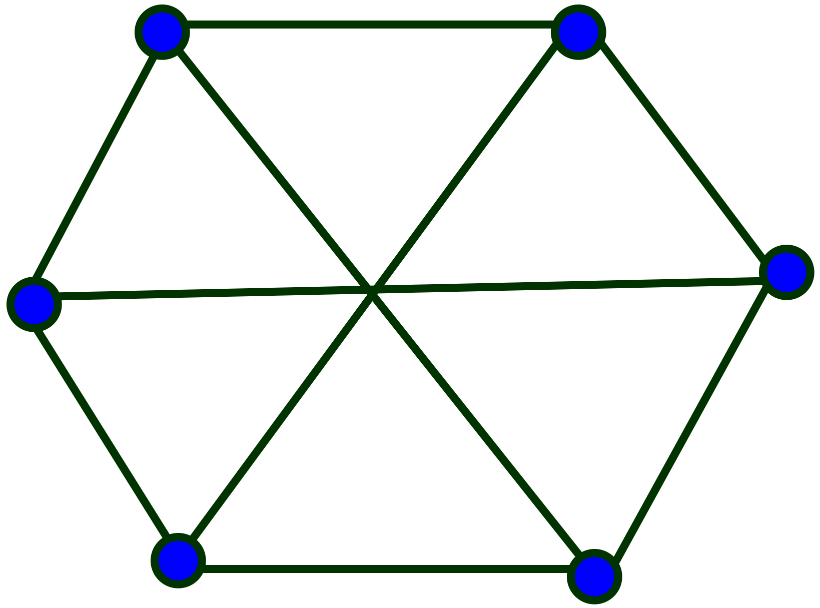
Mixed Control Team Organization

- 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

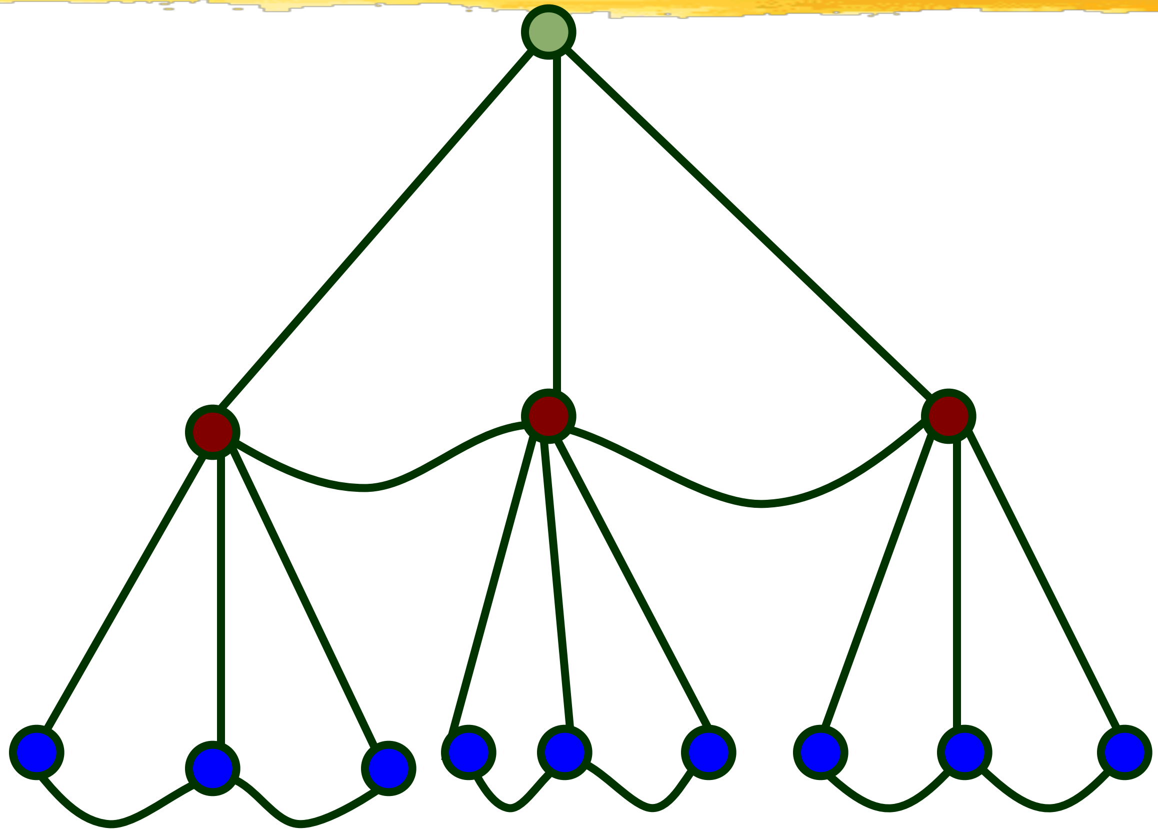


Chief Programmer team



Democratic Team

Mixed team organization



Summary

- We discussed the broad responsibilities of the project manager:
  - Project planning
  - Project Monitoring and Control

Summary

- 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 (CONT.)

- Cost estimation techniques:
  - Empirical Techniques
  - Heuristic Techniques
  - Analytical Techniques
- Empirical techniques:
  - based on systematic guesses by experts.
    - Expert Judgement
    - Delphi Estimation

Summary (CONT.)

- Heuristic techniques:
  - assume that characteristics of a software product can be modeled by a mathematical expression.
  - COCOMO
- Analytical techniques:
  - derive the estimates starting with some basic assumptions:
  - Halstead's Software Science

Summary (CONT.)

- The staffing level during the life cycle of a software product development:
  - follows Rayleigh curve
  - maximum number of engineers required during testing.

Summary (CONT.)

- Relationship between schedule change and effort:
  - highly nonlinear.
- Software organizations are usually organized in:
  - functional format
  - project format

Summary (CONT.)

- 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