SOFTWARE PROJECT MANAGEMENT

- Overview
- Software Project Metrics
- Software Project Estimation
- Software Project Planning

TOPICS

Overview

Metrics

Estimation

Planning

Overview

To successfully manage software development, the project leader must determine:

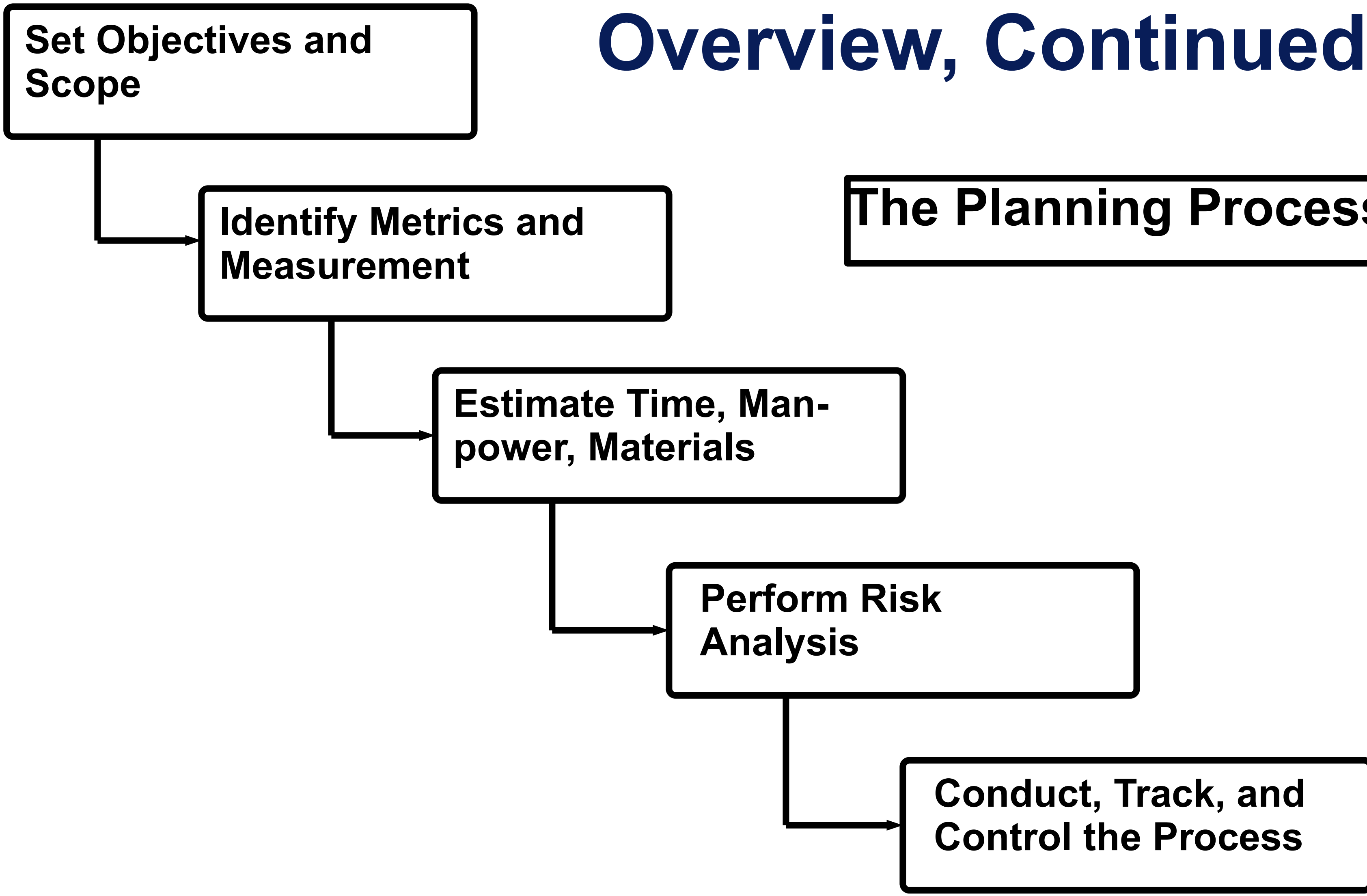
1. ***Scope*** **of work to be done**
2. ***Risks*** **to be incurred**
3. ***Resources*** **that will be required**
4. ***Tasks*** **to be accomplished**
5. ***Effort*** **(cost) that will be expended**
6. ***Schedule*** **to be followed**

Software project management begins before the technical work starts.

Software project management ends when the software is retired.

Overview, Continued

The Planning Process



SOFTWARE METRICS

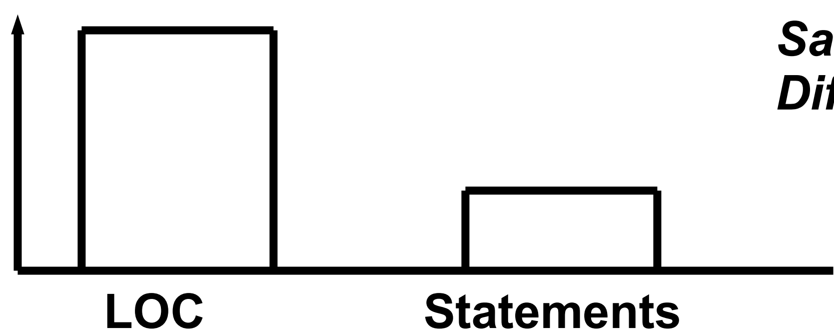
- Measuring Software
- Why Measure Software?
- Two Types of Measurements
- Categories of Metrics
- Size-Oriented Metrics
- Function Points
- Feature Points
- Function-Oriented Metrics
- Measuring Software Quality
- Relationship of LOC to FP
- Use of Productivity Data
- Integrating Metrics into the Software Engineering Process
- Collecting Software Metrics

Measuring Software

- Objectively measuring software is difficult.
  - Most projects use only "lines of code" (LOC) for metrics.
  - Much disagreement exists on what and how much to measure.

but

- Accurately measuring software is vitally important to tracking and controlling software development.



Same Project
Different Metrics

Why Measure Software?

To --

1. identify quality of the software product
2. assess productivity of the software developers
3. assess benefits of using development processes and tools
4. form a baseline for estimation
5. justify requests for tools and training

Two Types of Measurements

Direct

- -- cost
- -- LOC
- -- execution speed
- -- binary code size
- -- memory used

- easy to make

Indirect

- -- functionality
- -- quality
- -- "-ilities"

- not easy to make

Categories of Metrics

	Productivity	Quality	Technical
Size-Oriented			
Function-Oriented			
Human-Oriented			

Size-Oriented Metrics

Let *KLOC* = "thousand lines of code"

Then we can define

- *productivity = KLOC / person-months*
- *quality = defects in code / KLOC*
- *cost = dollars / KLOC*
- *documentation = pages of documents / KLOC*

Efforts and costs include all elements of software development (analysis, design, code, test, *etc.*).

Size-Oriented Metrics - Examples

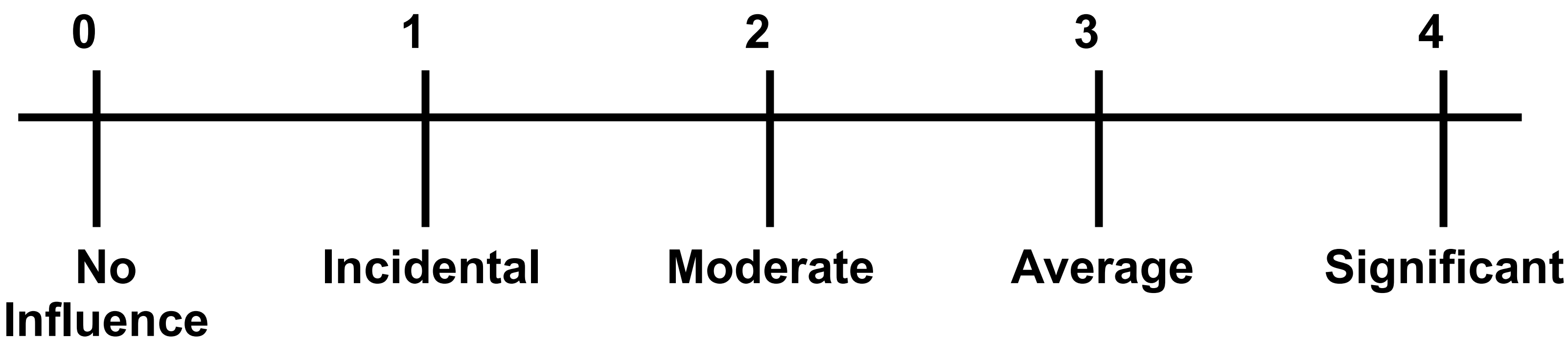
Project	Person-Months	Cost	KLOC	Pages of Doc	Errors
A	24	$168,000	12.1	365	29
B	62	$440,000	27.2	1224	86
C	43	$314,000	20.2	1050	64

Project	Productivity (KLOC/p-months)	Quality (errors/KLOC)	Cost ($/LOC)	Documents (pages/KLOC)
A	0.504	2.40	$13.88	30.17
B	0.439	3.55	$16.18	45.00
C	0.470	3.67	$15.54	51.98

Problems with Size-Oriented Metrics

- Definition of "lines of code"
  - Programming language dependent
  - Penalize well-designed shorter programs
  - Cannot easily accommodate non-procedural languages
  - Difficult to assess LOC before a program is written
- Only known errors can be counted
- Types, skill levels, and productivity of personnel varies

Function Points - Fi Values



1. Does the system require reliable backup? 8. Are the master files updated on-line?

2. Are data communications required? 9. Are the inputs, outputs, files, or inquiries complex?

3. Are there distributed processing functions? 10. Is the internal processing complex?

4. Is performance critical? 11. Is the code designed to be reusable?

5. Will the system run in an existing environment? 12. Are conversion and installation included in design?

6. Does the system require on-line data entry? 13. Is the system designed for multiple installations in

7. Does the on-line data entry require the input different organizations?

Function Points - Computation

Measurement Parameter	Count		Weighting Simple	Factor Average	Complex		Product
Number of user inputs		x	3	4	6	=	
Number of user outputs		x	4	5	7	=	
Number of user inquiries		x	3	4	6	=	
Number of files		x	7	10	15	=	
Number of external interfaces		x	5	7	10	=	

Count - Total →

$$FP = \text{count - total}(0.65 + 0.01 \sum F_i)$$

Feature Points

Function Point Extensions for Technical Software

- Function points were originally designed for business information systems applications.
- Extensions called *feature points* apply to technical software applications.
- Algorithms are a bounded computational problem that is included within a specific computer program.

Feature Points - Computation

Measurement Parameter	Count		Weight		Product
Number of user inputs		x	4	=	
Number of user outputs		x	5	=	
Number of user inquiries		x	4	=	
Number of files		x	7	=	
Number of external interfaces		x	7	=	
Algorithms		x	3	=	

Count - Total ⟶ [ ]

$$FP = \text{count total} \times (0.65 + 0.01 \times \sum F_i)$$

Problems with Function Points and Feature Points

1. These metrics are based on subjective data.
2. Parameters can be difficult to obtain after-the-fact.
3. Function and Feature Points have no direct physical meaning.

Function-Oriented Metrics

- Focus is on "functionality" or "utility"
- Both Function Points and Feature Points support the derivation of potentially useful data for the comparison of one project to another:

  - Productivity = FP / person-month
  - Quality = defects / FP
  - Cost = $ / FP
  - Documentation = pages / FP

Measuring Software Quality

Before Delivery

- Program complexity
- Effective modularity
- Program size

After Delivery (most widely used)

- Number of defects uncovered in the field
- Maintainability of the system

"After Delivery" Quality Metrics

- *Correctness* - defects/KLOC or defects/FP over a one-year period
- *Maintainability* - mean-time-to-change (MTTC), which is the time required to:
  - analyze the change request,
  - design a modification to the software,
  - implement the change,
  - test the changed software and the system as a whole, and
  - distribute the changed system to the users

"After Delivery" Quality Metrics, Continued

- ***Integrity*** **- based on threats and security**
  - ***Threat*** **- probability that a specific attack will take place within a given period of time**
  - ***Security*** **- probability that the attack of a specific type will be repelled**

$$\text{Integrity} = \sum_{\text{allthreats}} (1 - \text{threat} \times (1 - \text{security}))$$

- ***Useability*** **- based on several perceptions of the users:**
  - **skill required to use the program**
  - **time required to learn the use of the program**
  - **the increase in productivity from using the program**
  - **the user's attitude towards the program**

Relationship of LOC to FP

- The relationship of lines of code to feature points is a function of the programming language used and the quality of the design.
- Rough estimates of the number of lines of code to create on feature point are:

Language	*LOC/FP*
Assembly	300
COBOL	100
FORTRAN	100
Pascal	90
Ada	70
Object-Oriented Languages	30
Fourth Generation Languages	20
Automatic Code Generators	15

Use of Software Productivity Data

- Do not use LOC/person-month or FP/person-month to:
  - Compare one group of developers to another
  - Rate the performance of an individual
- Many factors affect productivity:

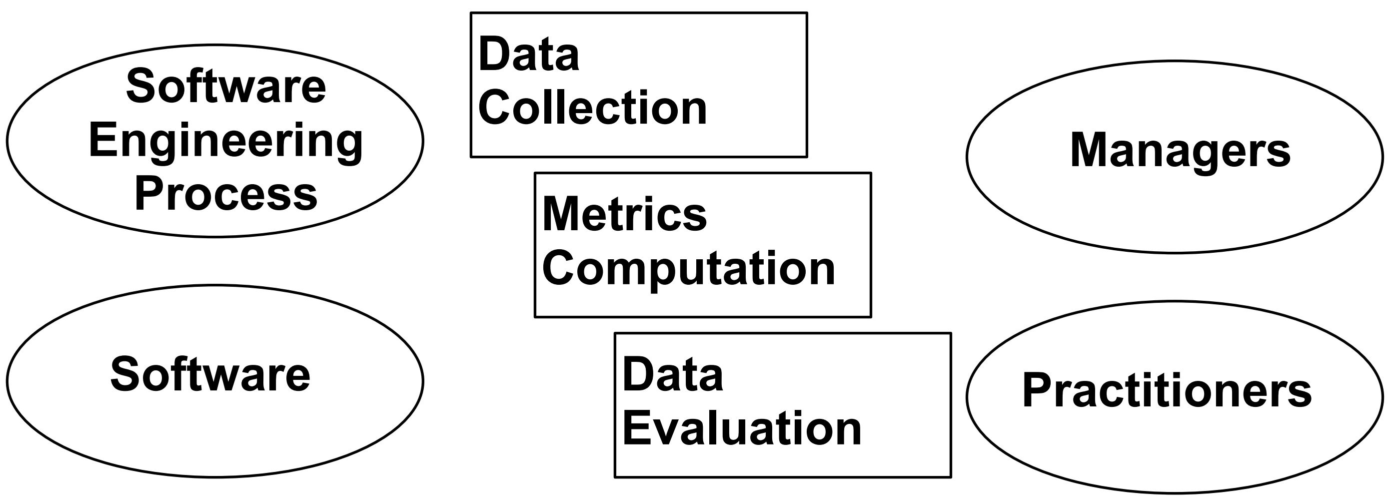
Factor	*Approximate % Variation in Productivity*
People (number, experience)	90%
Problem (complexity, number of changes)	40%
Process (language, CASE)	50%
Product (reliability, environment)	140%
Resources (CASE, hardware, software)	40%

Integrating Metrics into the Software Engineering Process

- A historical baseline of metrics data is needed:
  - Company, department, or unit should be identified in the scope of this data.
  - Resistance to data collection should be expected in many corporate cultures.
- At least three years of accurate, standardized metric data collection is needed to produce accurate planning estimates.

Collecting Software Metrics

- The process of collecting and using software metrics includes the following steps:
  1. data collection
  2. metrics computation
  3. data evaluation
- The following slides show a spreadsheet model for the collection and computation of historical software baseline data.



Spreadsheet Data Collection Model

Description	Units	Sample Data
Cost Data Input		
Labor cost	$/person-month	$7,744
Labor year	hours/year	1560
Data for Metrics Computation		
Release type	alphanumeric	maintenance
Number of staff members	people	3
Effort	person-hours	4800
Elapsed time to complete	hours	2000
Source code	KLOC	
Newly developed		11.5
Modified		0.4
Reused		0.8
Delivered		33.4

Spreadsheet Data Collection Model

Description	*Units*	*Sample Data*
Data for Metrics Computation, Continued		
Documentation	**pages**	
Technical		**265**
User		**122**
Number of errors to date	**numeric**	
Critical errors		**0**
Level 1 errors		**12**
Level 2 errors		**14**
Documentation errors		**40**
Maintenance to date	**person-hours**	
Modifications		**3550**
Error correction		**1970**

Spreadsheet Data Collection Model

Description	*Units*	*Sample Data*
Project Data	% of total	
Analysis and specification		18%
Design		20%
Coding		23%
Testing		25%
Other - Describe		14%

Spreadsheet Data Collection Model

Description	*Units*	*Sample Data*
Function-Oriented Data		
Information Domain		
1. No. of user inputs	inputs	24
2. No. of user outputs	outputs	46
3. No. of user inquiries	inquiries	8
4. No. of files	files	4
5. No. of ext. interfaces	interfaces	2
Weights		
1. No. of user inputs	3, 4, 6	4
2. No. of user outputs	4, 5, 7	4
3. No. of user inquiries	3, 4, 6	6
4. No. of files	7, 10, 15	10
5. No. of ext. interfaces	5, 7, 10	5

Spreadsheet Data Collection Model

Description	Units	Sample Data
Function-Oriented Data, Continued		
Processing Complexity Factors	0-5	
1. backup and recovery required		4
2. data communication required		1
3. distributed processing function		0
4. performance critical		3
5. heavily utilized operating environment		3
6. online data entry		5
7. input transaction with multiple screens		4
8. master files updated online		4
9. input, output, files, queries complex		3
10. internal processing complex		3
11. code designed to be reusable		2
12. conversion/installation included in design		2
13. system design for multiple installation		4
14. maintainability/ease of use		5

Spreadsheet Data Collection Model

Description	*Units*	*Sample Data*
Size-Oriented Metrics		
Productivity and Cost		
Output	KLOC/p-month	0.905
Cost - all code	$/KLOC	$22,514
Cost - exclude reuse	$/KLOC	$24,028
Elapsed time	months/KLOC	1.0
Documentation	pages/KLOC	30
Documentation	pages/p-month	10
Documentation	$/page	$739
Quality		
Defects	errors/KLOC	2.0
Cost of errors	$/error	$376

Spreadsheet Data Collection Model

Description	Units	Sample Data
Function-Oriented Metrics		
Productivity and Cost		
Output	FP/p-month	378
Cost - all code	$/FP	$700
Elapsed time	FP/month	31.4
Documentation	pages/FP	0.9
Quality		
Defects	errors/FP	0.064

SOFTWARE PROJECT ESTIMATION

- Overview
- Resources
- Decomposition Techniques
- Using LOC or FP to Estimate Effort
- Effort Estimation by Function
- Effort Estimation by Task
- Empirical Estimation Models
- COCOMO
- Putman Estimation Model

Overview

Estimation of:

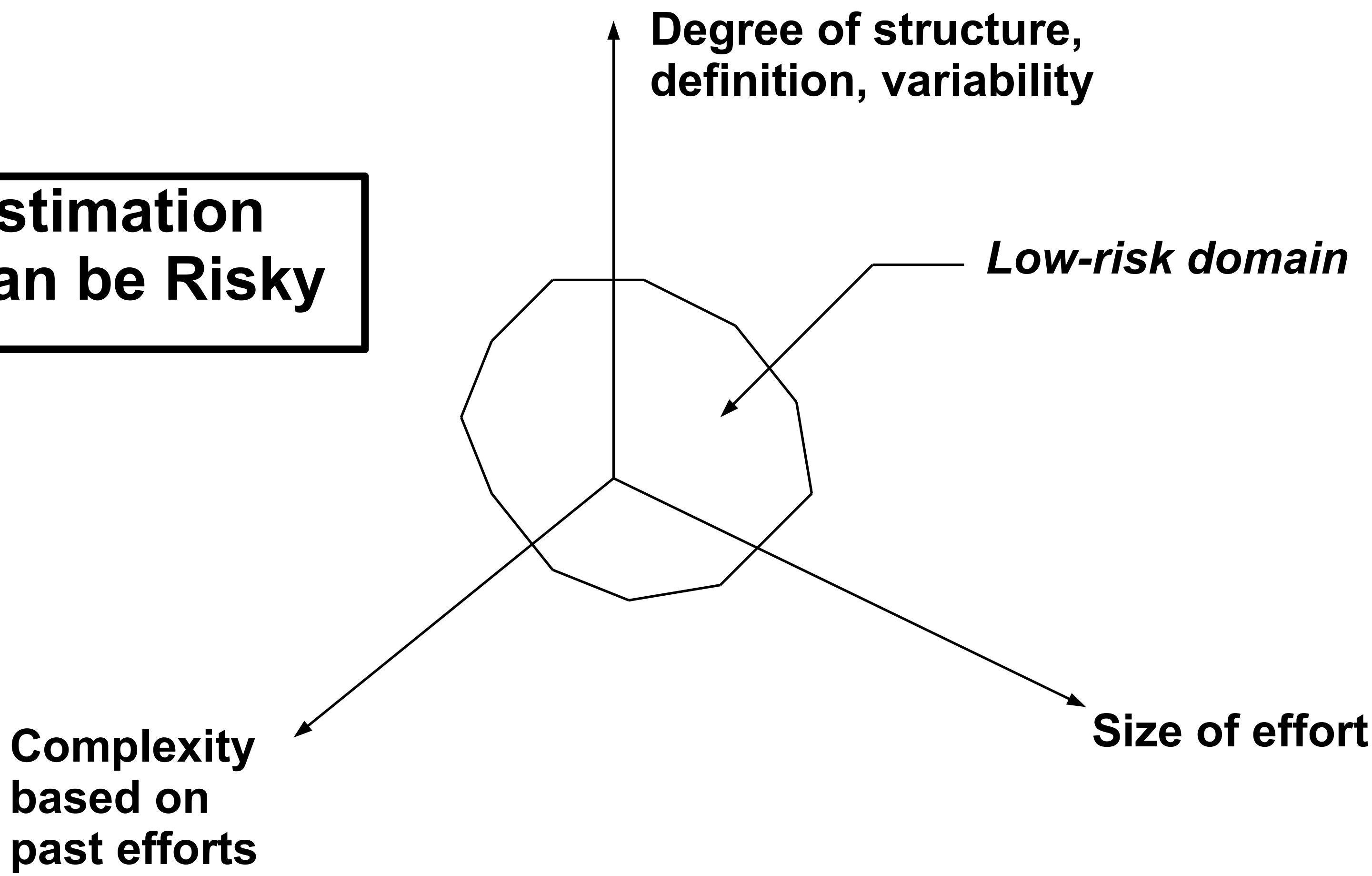
- resources
- costs
- schedules

Requires:

- experience
- historical information
- quantitative measures of qualitative data

Overview, Continued

Estimation can be Risky



Resources

Planning Task 1: Software Scope

1. Statement of software scope must be bounded
2. Software scope describes:
   - function
   - performance
   - constraints
   - interfaces
   - reliability

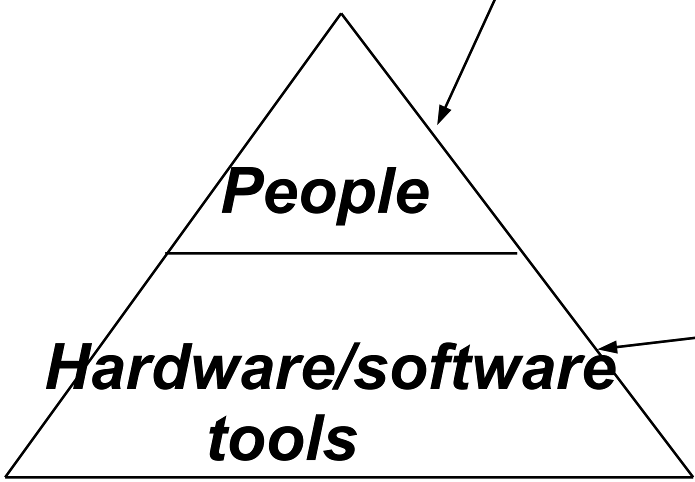
evaluated together (function, performance, constraints)

Resources, Continued

Planning Task 2: Estimation of Needed Resources

Specify:

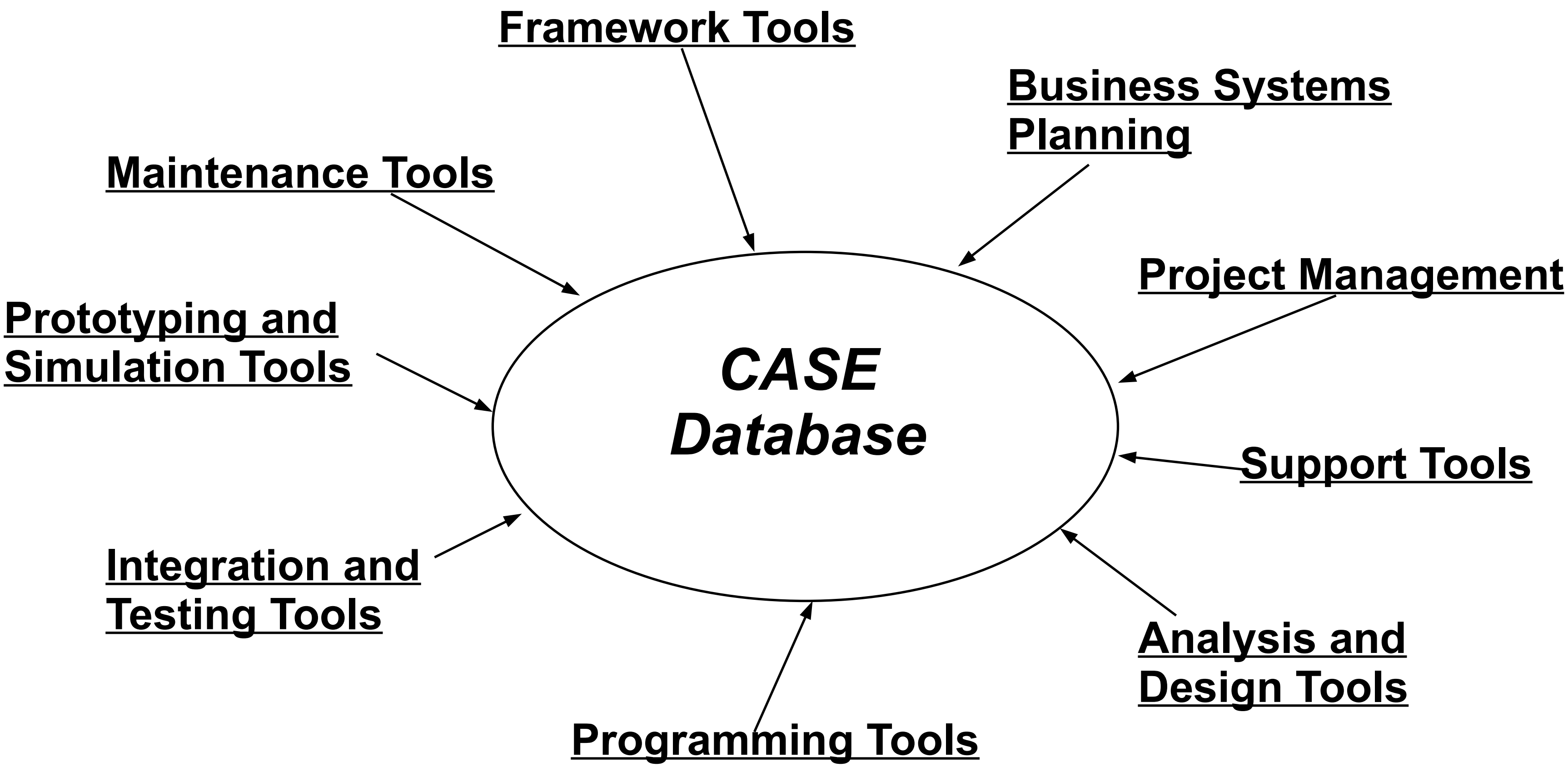
- Required skills
- Availability
- Duration of tasks
- Start date



Specify:

- Description
- Availability
- Duration of use
- Delivery date

Resources, Continued



CASE - Computer-Aided Software Engineering

Resources, Continued

Reuse - A Resource

Two rules:

1. If existing software meets requirements, then

acquire and use it!

2. If existing software can meet requirements with some modification, then

be careful!

The cost of modification can exceed the cost of new development!

Decomposition Techniques

- LOC and FP Estimation
- Effort Estimation

Decomposition Techniques, Continued

LOC and FP Estimation

The idea is that the person planning the software project:

- creates a bounded statement of the scope of the software
- decomposes the scope into smaller subfunctions
- estimates LOC or FP for each subfunction
- applies baseline productivity metrics (e.g., LOC/person-month) to LOC or FP estimates to produce a cost or effort estimate for each subfunction
- combines estimates for each subfunction to derive estimates for the entire project

Decomposition Techniques, Continued

Differences Between LOC and FP

- FP estimation techniques require less detail than LOC
- LOC is estimate directly while FP is estimated indirectly

Using LOC or FP to Estimate Effort

1. Estimate LOC or FP values for each subfunction
   - Use historical data (or intuition, if necessary)
   - Three estimates: optimistic (o), most likely (m), and pessimistic (b)
2. Calculate expected value for each subfunction $E = \frac{a + 4m + b}{6}$
3. Apply productivity data to get effort to be expended; two ways:
   1. Total expected LOC or FP for all subfunctions and divide this by the expected LOC or FP completed per person-month (estimated from past projects); example:

Effort = 310 expected FP for project/5.5 expected FP per person-month

= 56 person-months

   2. Multiply each subfunction LOC or FP by the adjusted productivity value (based on the estimated complexity of the function) and sum the results for all subfunctions in the project

Effort Estimation by Function

CAD Program Example

Function	*Optimistic*	*Most Likely*	*Pessimistic*	*Expected*	*$/Line*	*Line/Month*	*Cost*	*Months*
User interface control	1800	2400	2650	2,340	$14	315	$ 32,760	7.4
2-D geometric analysis	4100	5200	7400	5,380	$20	220	$107,600	24.4
3-D geometric analysis	4600	6900	8600	6,800	$20	220	$136,000	30.9
Data structure mgmt	2950	3400	3600	3,350	$18	240	$ 60,300	13.9
Graphics display	4050	4900	6200	4,950	$22	200	$108,900	24.7
Peripheral control	2000	2100	2450	2,140	$28	140	$ 59,920	15.2
Design analysis	6600	8500	9800	8,400	$18	300	$151,200	28.0
Estimated Effort				33,360			$656,680	144.5

Estimated Cost: $ 656,680
Estimated Effort: 144.5 person-months

Effort Estimation by Task

CAD Program Example

Function	*RA*	*Design*	*Code*	*Test*	*Total*
User interface control	1.0	2.0	0.5	3.5	7.0
2-D geometric analysis	2.0	10.0	4.5	9.5	26.0
3-D geometric analysis	2.5	12.0	6.0	11.0	31.5
Data structure mgmt	2.0	6.0	3.0	4.0	15.0
Graphics display	1.5	11.0	4.0	10.5	27.0
Peripheral control	1.5	6.0	3.5	5.0	16.0
Design analysis	4.0	14.0	5.0	7.0	30.0
Total	14.5	61.0	26.5	50.5	152.5
Rate ($)		5200	4800	4250	4500
Cost ($)	75,400	292,800	112,625	227,250	708,075

Estimated Cost: $ 708,075

Estimated Effort: 152.5 person-months

Empirical Estimation Models

- **Static single-variable model (example: COCOMO)**

$$Resource = cx^d$$

where

x is the estimated characteristic (LOC, FP, effort, etc.)

c and d are constants derived from data collected from past projects

- **Static multivariable model**

$$Resource = cx + dy + \ldots$$

where

x, y, ... and c, d, ... are as above

- **Dynamic multivariable model**

Project resource requirements are determined over a series of time steps

- **Theoretical (example: Putman Estimation Model)**

Uses equations derived from hypothesized expenditure curves

COCOMO

- Involves basic, intermediate, and advanced models
- Basic model:

$$Effort = a(b)KLOC^{b(b)} \text{ person-month}$$

$$Development\_Time = c(b)Effort^{d(b)} \text{ month}$$

a(b), b(b), c(b), and d(b) are determined from the table:

Software Project	*a(b)*	*b(b)*	*c(b)*	*d(b)*
Organic	2.4	1.05	2.5	0.38
Semidetached	3.0	1.12	2.5	0.35
Embedded	3.6	1.20	2.5	0.32

COCOMO, Continued

Example of COCOMO basic model on the CAD program:

Effort = 3.0 (LOC) ^ 1.12

= 3.0 (33.3) ^ 1.12

= 152 person-months

Development Time = 2.5 (Effort) ^ 0.35

= 2.5 (152) ^ 0.35

= 14.5 months

Thus, estimated number of people N is:

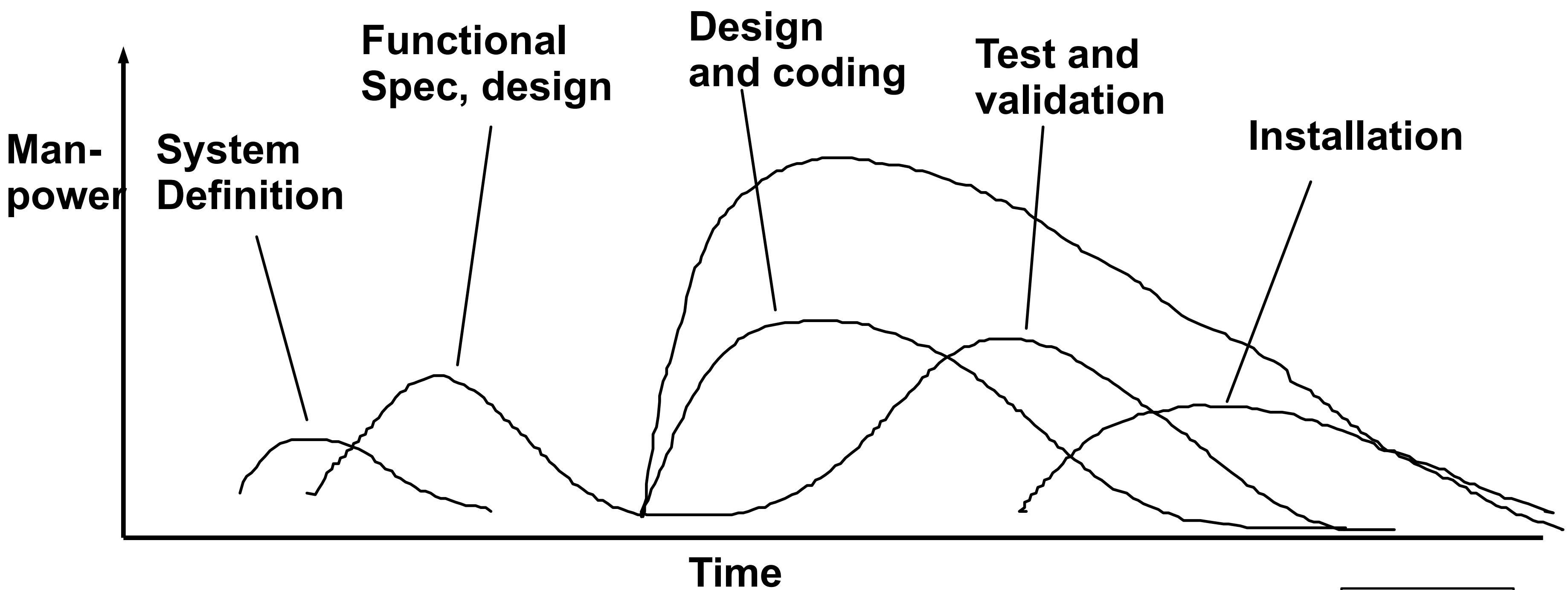
N = Effort / Development Time

= 152 / 14.5

= 11 people

Putman Estimation Model

- Data is derived from large projects
- Model is applicable to smaller projects as well
- The distribution of effort is described by the Rayleigh-Norden curve



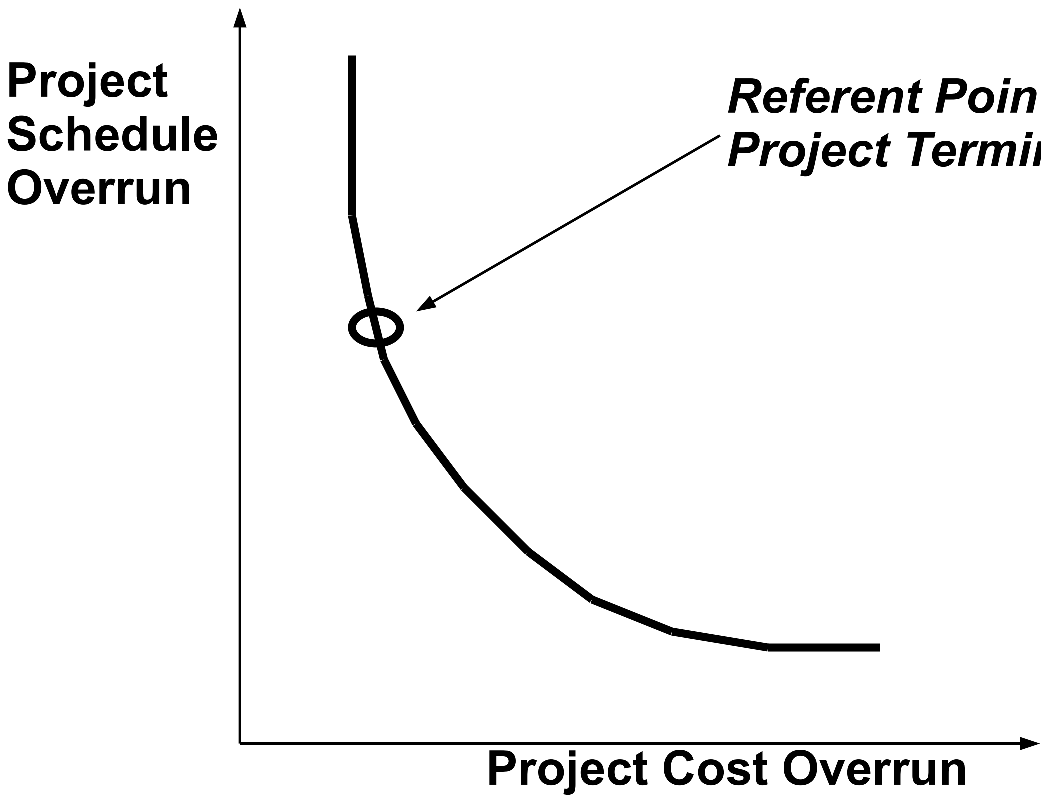
SOFTWARE PROJECT PLANNING

- What Software Project Planning Involves
- Risk Analysis
- Risk Management
- Risk Monitoring - Project Tracking
- Software Project Scheduling
- Typical Task Network
- Approaches to Project Tracking
- Software Acquisition
- Software Acquisition Decision Tree
- Software Re-Engineering
- Organizational Planning
- Enhancements to a Good Organization
- The Software Project Plan (SPP)

What Software Project Planning Involves

1. *Estimation*
2. **Risk Analysis**
3. **Scheduling**
4. **Acquisition Decision Making**
5. **Re-Engineering**
6. **Organizational Planning**

Risk Analysis



Risk Management

- Create risk management and monitoring plan
- For each risk triplet, define the risk management steps
- Risk management incurs additional project cost
- For larger projects, there may be 30-40 risks identified

Example

Assume:

Risk = High staff turnover

Likelihood of occurrence = 70%

Impact = Increase project time by 15%, project cost by 12%

Risk Management steps may be:

1. Identify high turnover causes
2. Reduce causes before project starts
3. Develop techniques to assure work continuity in light of turnover

Risk Monitoring - Project Tracking

1. Determine if predicted risk occurs
2. Properly apply risk aversion steps
3. Collect info for future risk analysis

Software Project Scheduling

- People-work relationships
- Task definition and parallelism
- Effort distribution
- Scheduling methods
- An example

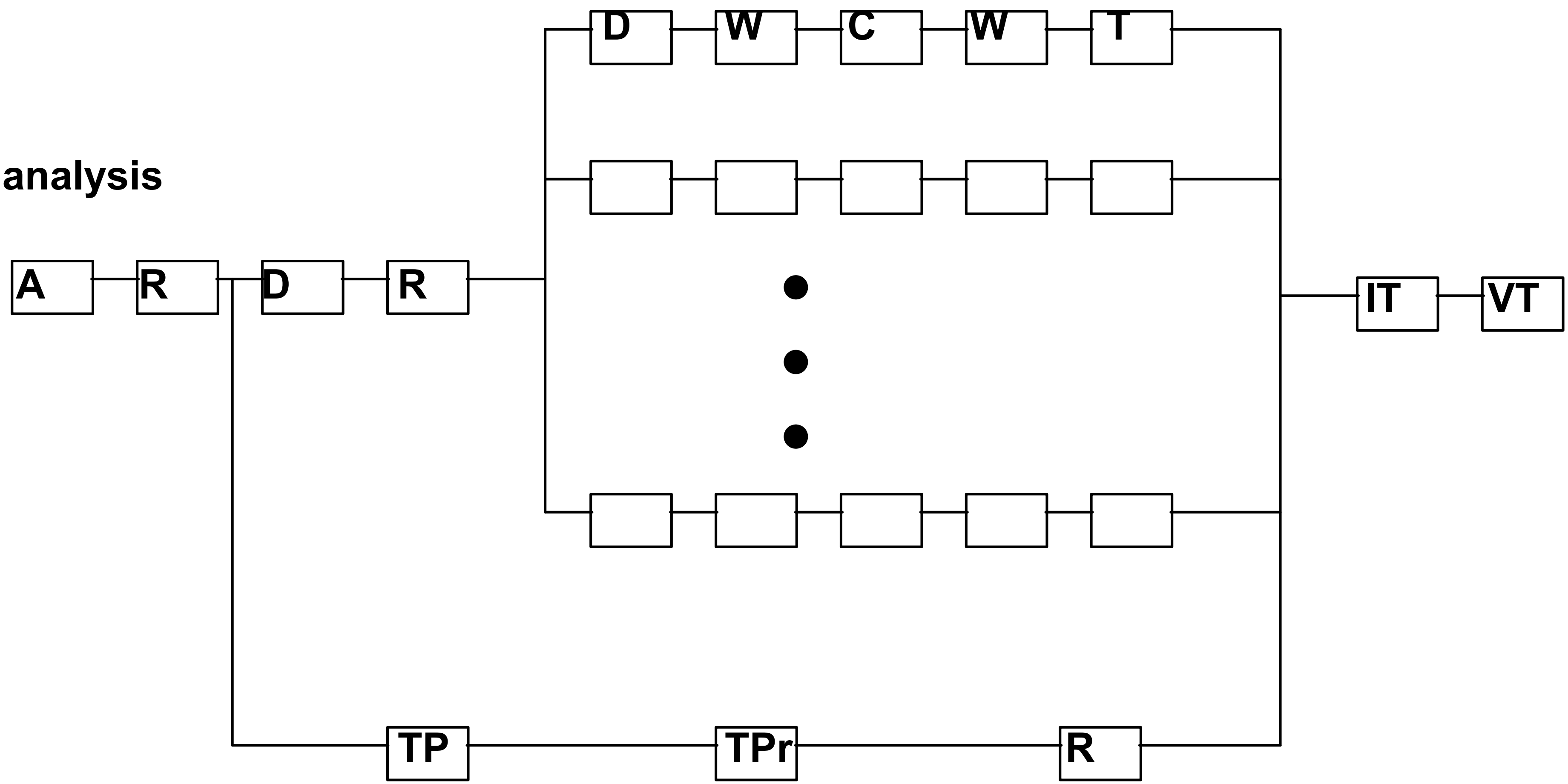
Software Project Scheduling

People-Work Relationships

- Adding people to a project when behind schedule is counterproductive (*adding people to a late project makes it later*)
- Using fewer people over a longer period of time is more beneficial than lots of people for a shorter period of time
- Use of small, tightly-knit teams is productive
- Inspire creativity and self-motivation within the structure of the project

Software Project Scheduling

Task Definition and Parallelism



Software Project Scheduling

Task Definition and Parallelism

Initial Sequential Events

Milestone 1 Occurs After --

- System analysis and specification
- System requirements review

Milestone 2 Occurs After --

- System architecture and data design
- System preliminary design review

Software Project Scheduling

Task Definition and Parallelism

Parallel Events for Each Subfunction

Milestone P1 Occurs After --

- Procedural design
- Design walkthrough

Milestone P2 Occurs After --

- Coding
- Code walkthrough

Milestone P3 Occurs After --

- Unit testing

Software Project Scheduling

Task Definition and Parallelism

System Testing Activities Can Be Performed In Parallel

Testing Milestone (After Unit Testing) --

- System test planning
- System test procedure
- System test review

Software Project Scheduling

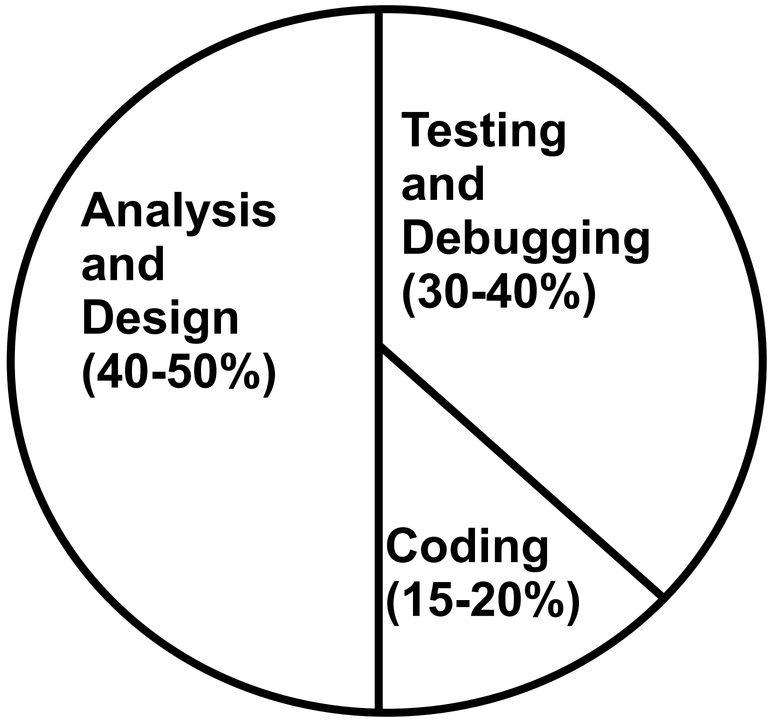
Task Definition and Parallelism

Integration Test Milestone - completed after system is assembled

Validation Test Milestone - completed last

Software Project Scheduling

Effort Distribution



Software Project Scheduling

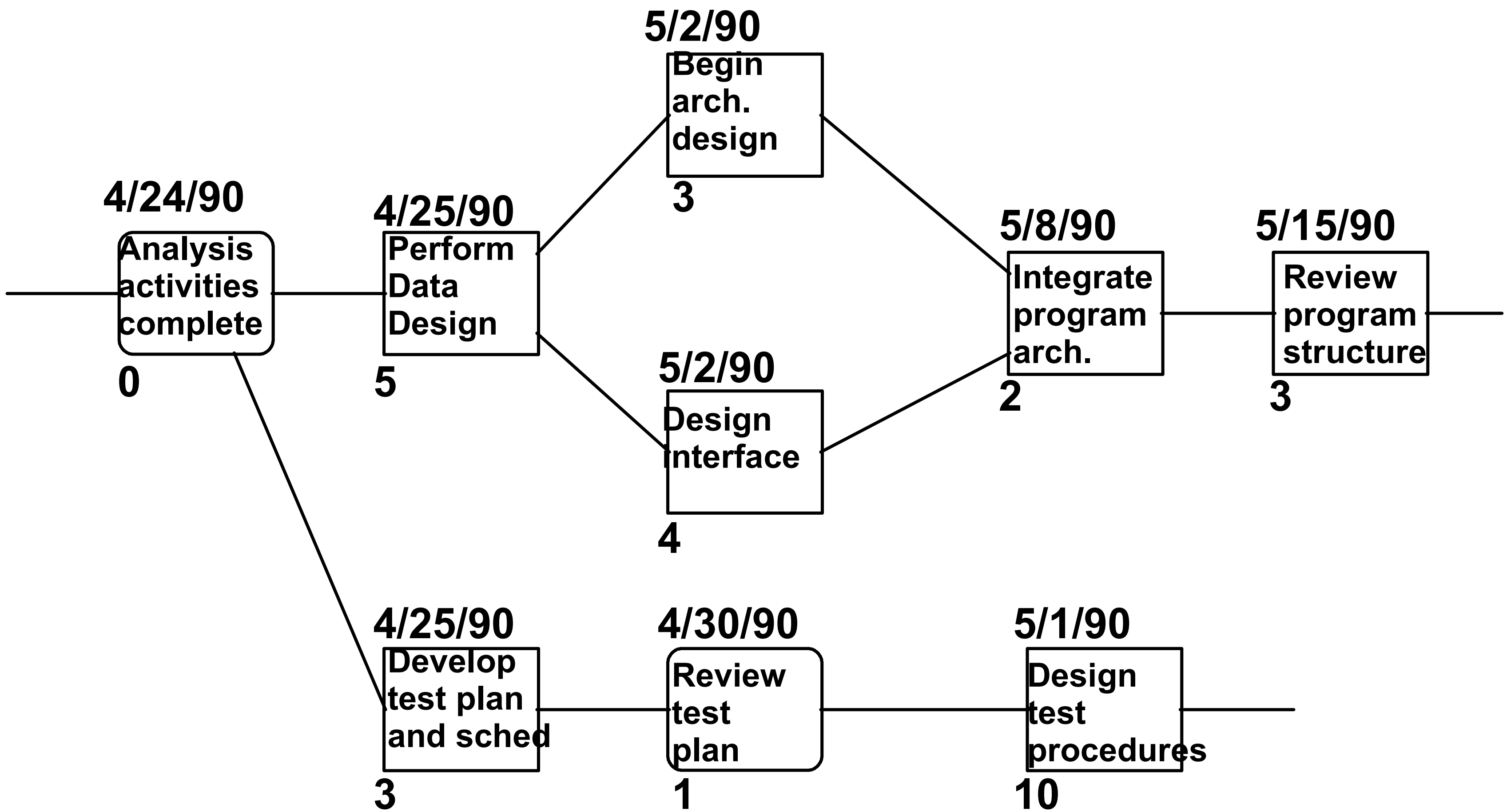
Scheduling Methods

- PERT - *Program Evaluation and Review Technique*
- CPM - *Critical Path Method*

PERT and CPM are:

- Usually presented pictorially
- Quantitative tools for the planner to determine:
  - Critical path
  - Most likely time estimates
  - Boundary times (earliest task start time, latest task start time, earliest task finish time, latest task finish time, total float time)

Typical Task Network



Approaches to Project Tracking

- Conducting periodic project status meetings in which each team member reports progress and problems
- Evaluating the results of all reviews conducted throughout the engineering process
- Determining whether formal project milestones have been accomplished by the scheduled date
- Comparing the actual start date to the planned start date for each task
- Meeting informally with software engineers to obtain their subjective assessments of the progress to date and problems on the horizon

Software Acquisition

- Make or buy?
  - Who will use?
  - Buy and modify?
  - Contact outside contractor to build?
- Decision based on:
  - Reduced cost
  - Earlier delivery date
  - Not enough or properly skilled people to develop
  - Better support outside

Software Acqusition Decision Tree

Approach *Cost*

Build **Simple** **$380,000**

Difficult **$450,000**

Reuse **Minor changes** **$275,000**

Major changes **Simple**

$310,000

Complex

$490,000

Buy **Minor changes** **$210,000**

Major changes

$400,000

Contract **Without changes** **$350,000**

With changes

$500,000

Software Re-Engineering

- For often-used programs, build a controlled database of components for all to use.
- Include documents, source code, user's guide, maintenance guide, test procedures and data, and a history of use with the components.
- Software re-engineering may be enhanced by object-oriented design and implementation.

Organizational Planning

- There are lots of human organizational structures for software development
- Possibilities - consider N people working for K years on M different functional tasks

			Level of
	Approach	*Interaction*	*Coordination*
	1 Assign N people to M tasks	Individual	Project Mgr
		(M > N)	
	2 Assign N people to M tasks	Teams	Project Mgr,
		(M < N)	Team Leader
	3 Assign N people to T teams,	Formal	Project Mgr,
		each team resp. for 1 or	
Teams	Team Leader		
		more tasks	

Enhancements to a Good Organization

- The Chief Programmer Team
- The Software Librarian
- Egoless programming with a team environment

The Software Project Plan (SPP)

A brief document which describes --

- The scope of the project
- The resources to be used
- Risks and risk avoidance techniques
- Cost and schedule
- Overall approach to software development

Management, technical staff, and customer are the primary reads of the SPP.

The SPP provides a starting point for the rest of the project.