PLANNING AND ESTIMATING

Adapted from Schach

Planning and Estimating

- Before starting to build software, it is essential to plan the *entire* development effort *in detail*

- Planning continues during development and then postdelivery maintenance
  - Initial planning is not enough
  - Planning must proceed throughout the project
  - The earliest possible time that detailed planning can take place is after the specifications are complete

Planning and the Software Process

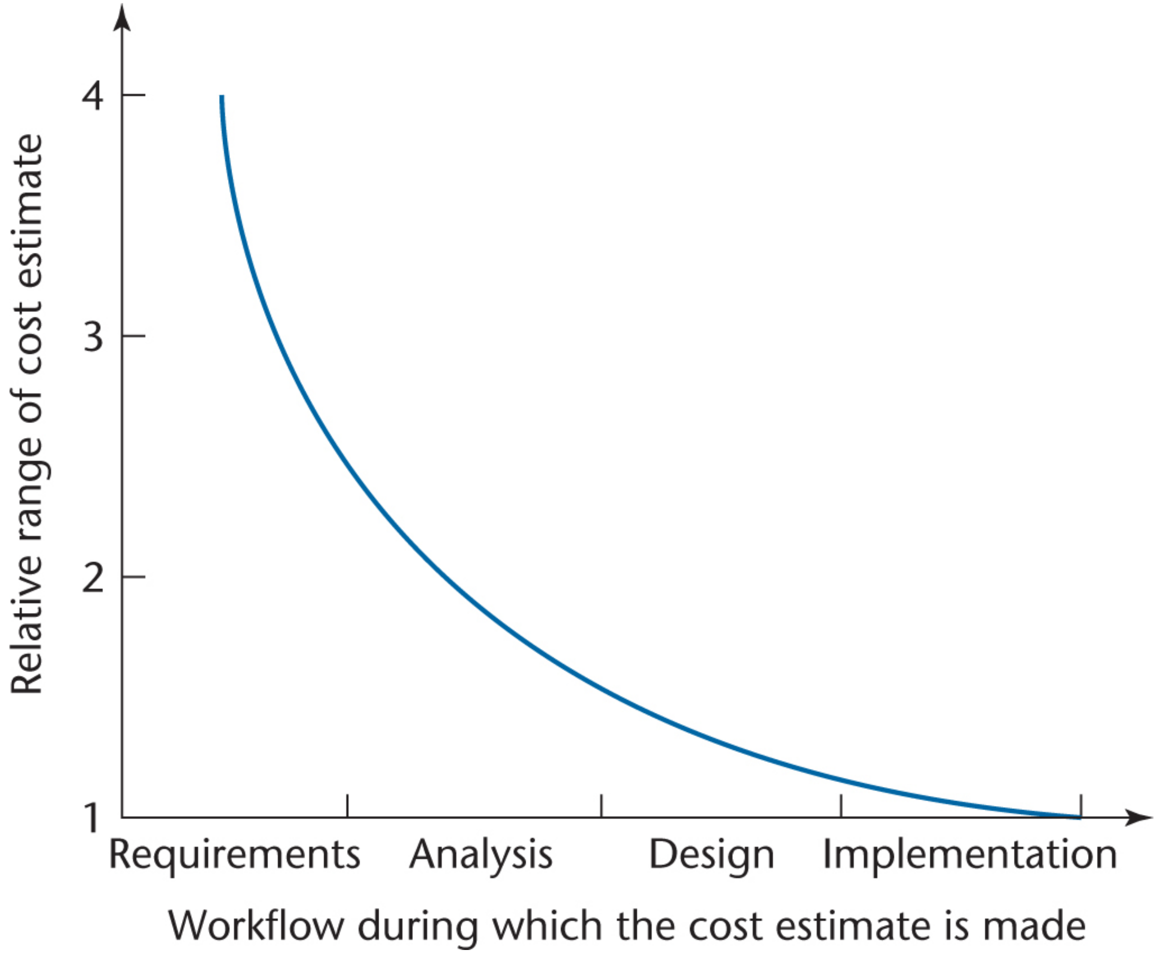


Figure 9.1

- The accuracy of estimation increases as the process proceeds

Planning and the Software Process (contd)

- Example
  - Cost estimate of $1 million during the requirements workflow
    - Likely actual cost is in the range ($0.25M, $4M)
  - Cost estimate of $1 million at the end of the requirements workflow
    - Likely actual cost is in the range ($0.5M, $2M)
  - Cost estimate of $1 million at the end of the analysis workflow (earliest appropriate time)
    - Likely actual cost is in the range ($0.67M, $1.5M)

Planning and the Software Process (contd)

- These four points are shown in the *cone of uncertainty*

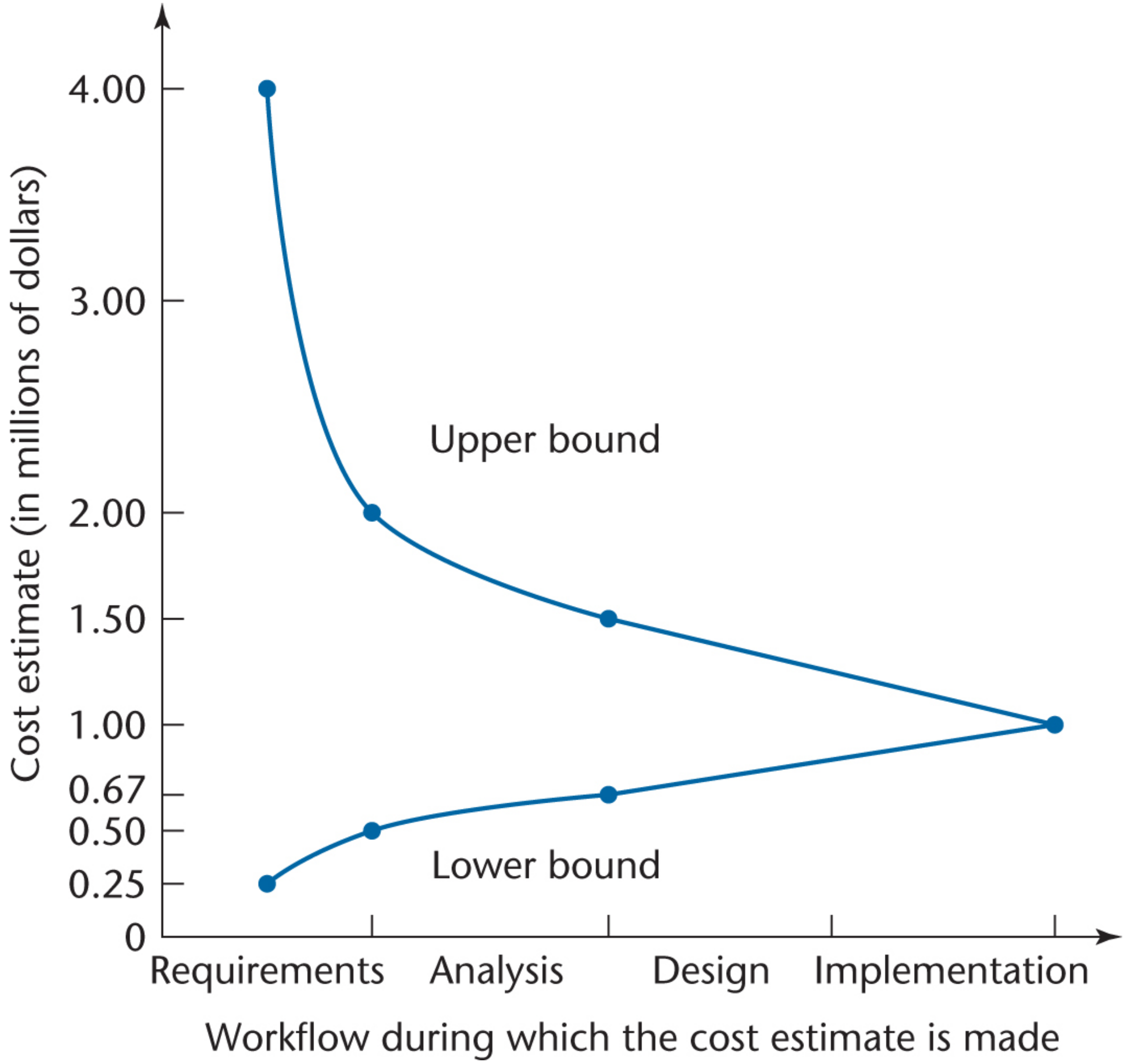


Figure 9.2

Planning and the Software Process (contd)

- This model is old (1976)
  - Estimating techniques have improved
  - But the shape of the curve is likely to be similar

9.2 Estimating Duration and Cost

- Accurate duration estimation is critical
- Accurate cost estimation is critical
  - Internal, external costs
- There are too many variables for accurate estimate of cost or duration

Human Factors

- Sackman (1968) measured differences of up to 28 to 1 between pairs of programmers
  - He compared matched pairs of programmers with respect to
    - Product size
    - Product execution time
    - Development time
    - Coding time
    - Debugging time
- Critical staff members may resign during the project

9.2.1 Metrics for the Size of a Product

- Lines of code (LOC, KDSI, KLOC)
- FFP
- Function Points
- COCOMO

Lines of Code (LOC)

- Alternate metric
  - Thousand delivered source instructions (KDSI)

- Source code is only a small part of the total software effort

- Different languages lead to different lengths of code

- LOC is not defined for nonprocedural languages (like LISP)

Lines of Code (contd)

- It is not clear how to count lines of code
  - Executable lines of code?
  - Data definitions?
  - Comments?
  - JCL statements?
  - Changed/deleted lines?
- Not everything written is delivered to the client
- A report, screen, or GUI generator can generate thousands of lines of code in minutes

Lines of Code (contd)

- LOC is accurately known only when the product finished

- Estimation based on LOC is therefore doubly dangerous
  - To start the estimation process, LOC in the finished product must be estimated
  - The LOC estimate is then used to estimate the cost of the product — an uncertain input to an uncertain cost estimator

Metrics for the Size of a Product (contd)

- Metrics based on measurable quantities that can be determined early in the software life cycle
  - FFP
  - Function points

FFP Metric

- For cost estimation of medium-scale data processing products

- The three basic structural elements of data processing products
  - Files
  - Flows
  - Processes

FFP Metric (contd)

- Given the number of files (*Fi*), flows (*Fl*), and processes (*Pr*)
  - The size (*s*), cost (*c*) are given by

$$S = Fi + Fl + Pr$$

$$C = b \times S$$

- The constant *b* (efficiency or productivity) varies from organization to organization

FFP Metric (contd)

- The validity and reliability of the FFP metric were demonstrated using a purposive sample
  - However, the metric was never extended to include databases

Function Points

- Based on the number of inputs (*Inp*), outputs (*Out*), inquiries (*Inq*), master files (*Maf*), interfaces (*Inf*)

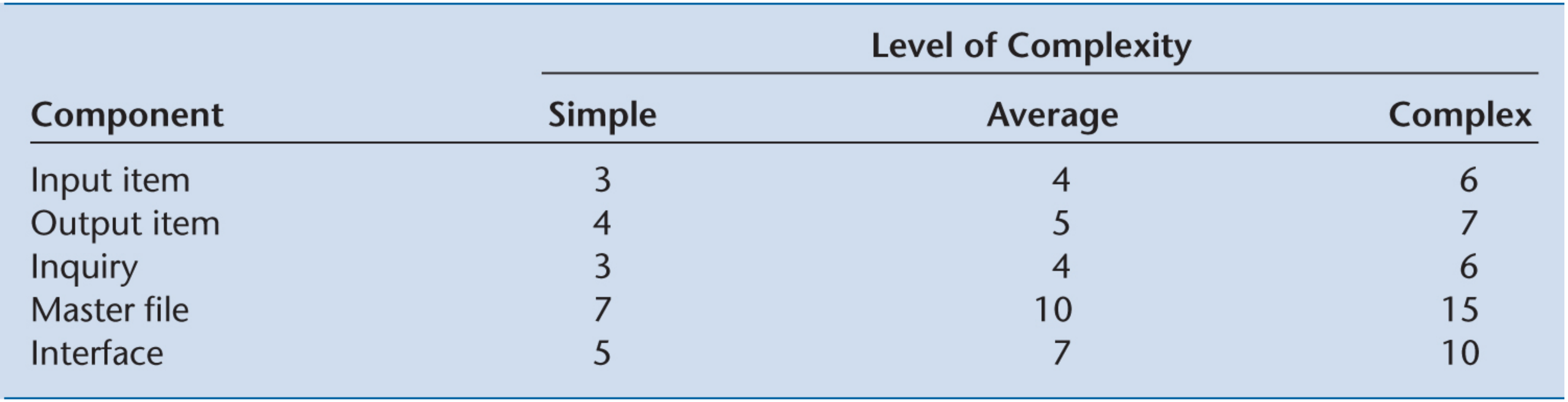
- For any product, the size in “function points” is given by

$$FP = 4 \times Inp + 5 \times Out + 4 \times Inq + 10 \times Maf + 7 \times Inf$$

- This is an oversimplification of a 3-step process

Function Points (contd)

- Step 1. Classify each component of the product (*Inp, Out, Inq, Maf, Inf*) as simple, average, or complex
  - – Assign the appropriate number of function points
  - – The sum gives *UFP* (unadjusted function points)

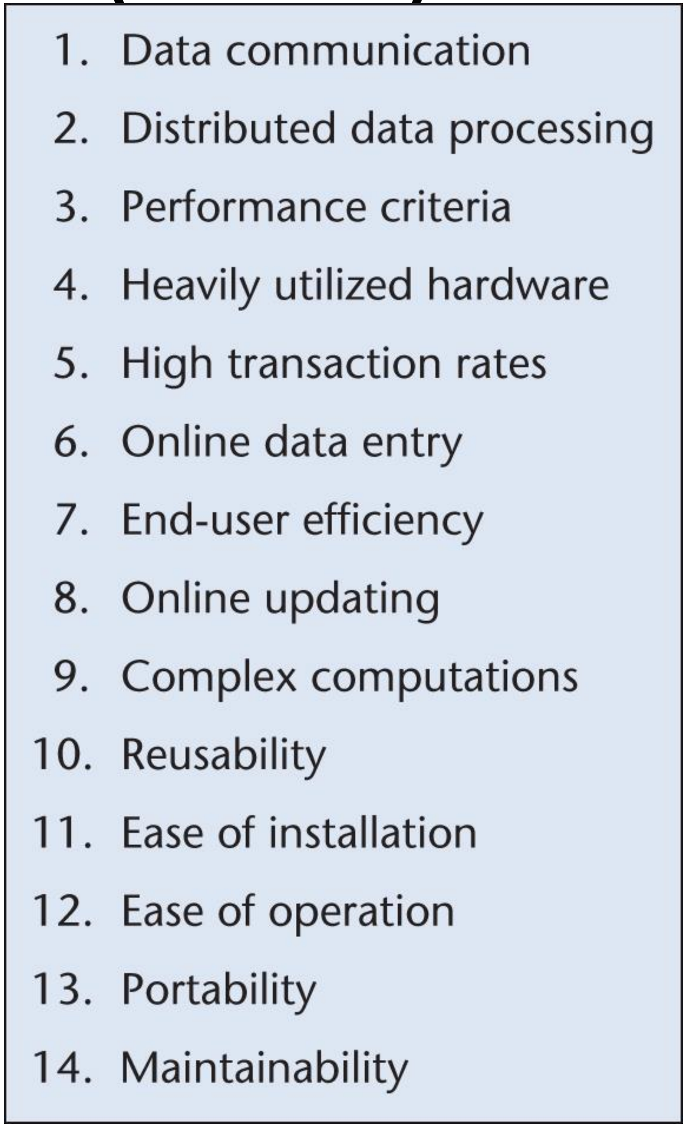


	Level of Complexity		
Component	**Simple**	**Average**	**Complex**
Input item	3	4	6
Output item	4	5	7
Inquiry	3	4	6
Master file	7	10	15
Interface	5	7	10

Figure 9.3

Function Points (contd)

- Step 2. Compute the technical complexity factor (*TCF*)
  - – Assign a value from 0 (“not present”) to 5 (“strong influence throughout”) to each of 14 factors such as transaction rates, portability



1. Data communication
2. Distributed data processing
3. Performance criteria
4. Heavily utilized hardware
5. High transaction rates
6. Online data entry
7. End-user efficiency
8. Online updating
9. Complex computations
10. Reusability
11. Ease of installation
12. Ease of operation
13. Portability
14. Maintainability

Figure 9.4

Function Points (contd)

- Add the 14 numbers
  - This gives the total degree of influence (*DI*)

$$TCF = 0.65 + 0.01 \times DI$$

- The technical complexity factor (*TCF*) lies between 0.65 and 1.35

Function Points (contd)

- Step 3. The number of function points (*FP*) is then given by

$$FP = UFP \times TCF$$

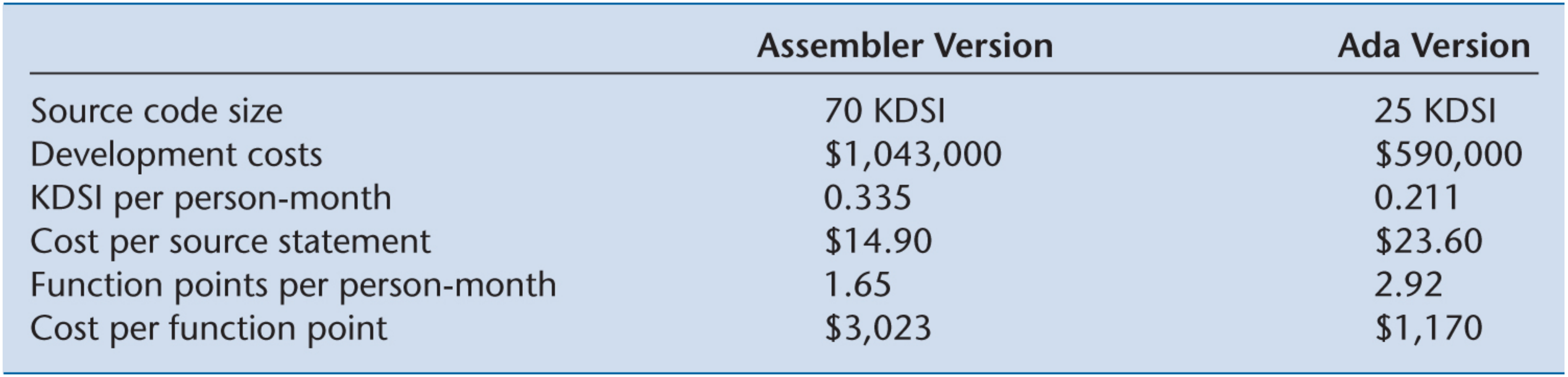
Analysis of Function Points

- Function points are usually better than KDSI — but there are some problems

- “Errors in excess of 800% counting KDSI, but *only* 200% in counting function points” [Jones, 1987]

Analysis of Function Points

- We obtain nonsensical results from metrics
  - – KDSI per person month and
  - – Cost per source statement



	Assembler Version	Ada Version
Source code size	70 KDSI	25 KDSI
Development costs	$1,043,000	$590,000
KDSI per person-month	0.335	0.211
Cost per source statement	$14.90	$23.60
Function points per person-month	1.65	2.92
Cost per function point	$3,023	$1,170

Figure 9.5

- Cost per function point is meaningful

Analysis of Function Points

- Like FFP, maintenance can be inaccurately measured
- It is possible to make major changes without changing
  - The number of files, flows, and processes; or
  - The number of inputs, outputs, inquiries, master files, and interfaces
- In theory, it is possible to change every line of code with changing the number of lines of code

Mk II Function Points

- This metric was put forward to compute *UFP* more accurately

- We decompose software into component transactions, each consisting of input, process, and output

- Mark II function points are widely used all over the world

9.2.2 Techniques of Cost Estimation

- Expert judgment by analogy
- Bottom-up approach
- Algorithmic cost estimation models

Expert Judgment by Analogy

- Experts compare the target product to completed products
  - Guesses can lead to hopelessly incorrect cost estimates
  - Experts may recollect completed products inaccurately
  - Human experts have biases
  - However, the results of estimation by a broad group of experts may be accurate

- The Delphi technique is sometimes needed to achieve consensus

Bottom-up Approach

- Break the product into smaller components
  - The smaller components may be no easier to estimate
  - However, there are process-level costs

- When using the object-oriented paradigm
  - The independence of the classes assists here
  - However, the interactions among the classes complicate the estimation process

Algorithmic Cost Estimation Models

- A metric is used as an input to a model to compute cost and duration
  - An algorithmic model is unbiased, and therefore superior to expert opinion
  - However, estimates are only as good as the underlying assumptions

- Examples
  - SLIM Model
  - Price S Model
  - COnstructive COst MOdel (COCOMO)

9.2.3 Intermediate COCOMO

- COCOMO consists of three models
  - A macro-estimation model for the product as a whole
  - Intermediate COCOMO
  - A micro-estimation model that treats the product in detail

- We examine intermediate COCOMO

Intermediate COCOMO (contd)

- Step 1. Estimate the length of the product in KDSI

Intermediate COCOMO (contd)

- Step 2. Estimate the product development mode (organic, semidetached, embedded)

- Example:
  - Straightforward product (“organic mode”)

    Nominal effort = 3.2 ´ (KDSI)$^{1.05}$ person-months

Intermediate COCOMO (contd)

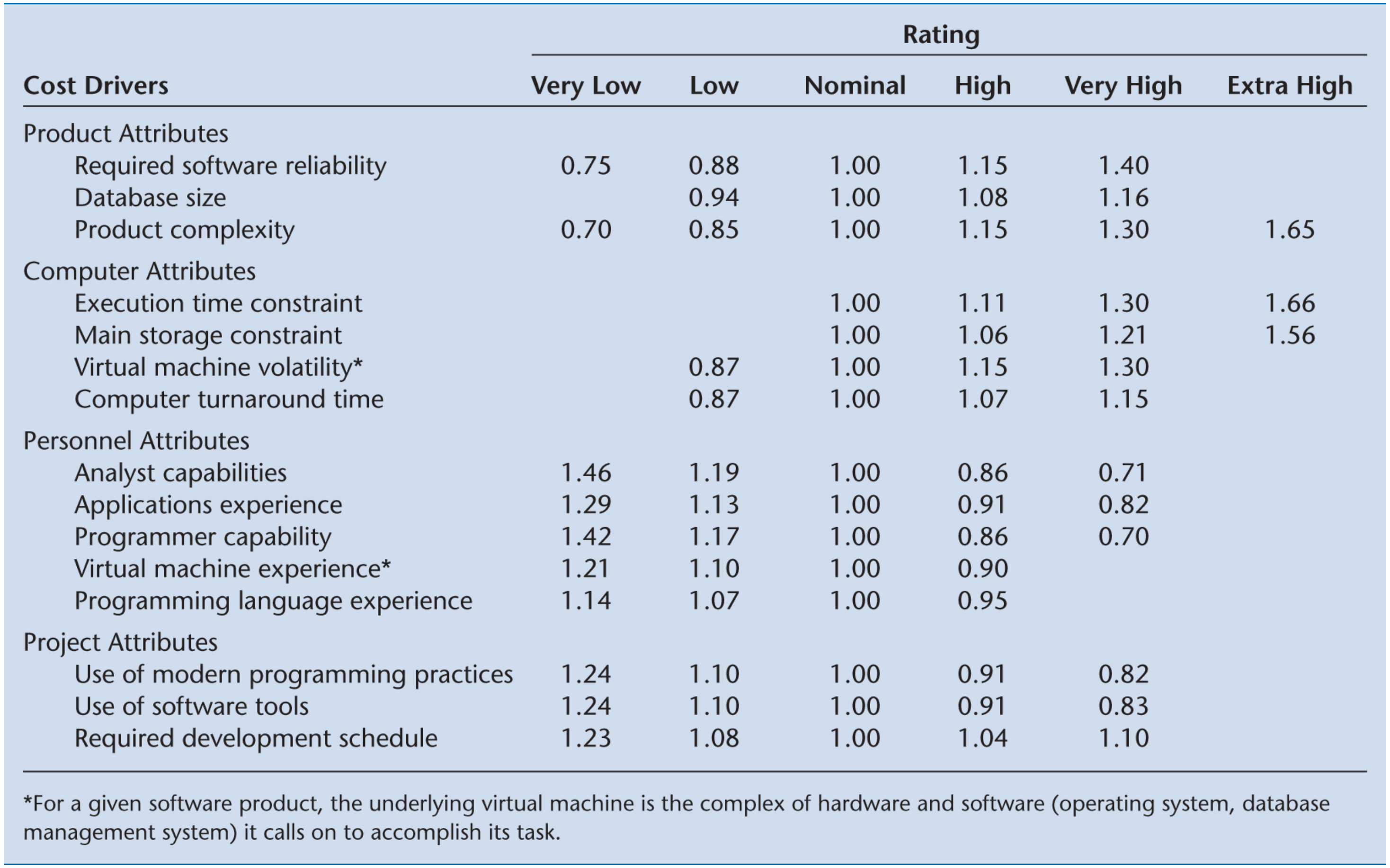
- Step 3. Compute the nominal effort

- Example:
  - – Organic product
  - – 12,000 delivered source statements (12 KDSI) (estimated)

  Nominal effort = 3.2 ´ $(12)^{1.05}$ = 43 person-months

Intermediate COCOMO (contd)

- Step 4. Multiply the nominal value by 15 software development cost multipliers



	Rating					
Cost Drivers	**Very Low**	**Low**	**Nominal**	**High**	**Very High**	**Extra High**
Product Attributes						
Required software reliability	0.75	0.88	1.00	1.15	1.40	
Database size		0.94	1.00	1.08	1.16	
Product complexity	0.70	0.85	1.00	1.15	1.30	1.65
Computer Attributes						
Execution time constraint			1.00	1.11	1.30	1.66
Main storage constraint			1.00	1.06	1.21	1.56
Virtual machine volatility*		0.87	1.00	1.15	1.30	
Computer turnaround time		0.87	1.00	1.07	1.15	
Personnel Attributes						
Analyst capabilities	1.46	1.19	1.00	0.86	0.71	
Applications experience	1.29	1.13	1.00	0.91	0.82	
Programmer capability	1.42	1.17	1.00	0.86	0.70	
Virtual machine experience*	1.21	1.10	1.00	0.90		
Programming language experience	1.14	1.07	1.00	0.95		
Project Attributes						
Use of modern programming practices	1.24	1.10	1.00	0.91	0.82	
Use of software tools	1.24	1.10	1.00	0.91	0.83	
Required development schedule	1.23	1.08	1.00	1.04	1.10	

*For a given software product, the underlying virtual machine is the complex of hardware and software (operating system, database management system) it calls on to accomplish its task.

Figure 9.6

Intermediate COCOMO (contd)

- Example:
  - Microprocessor-based communications processing software for electronic funds transfer network with high reliability, performance, development schedule, and interface requirements

- Step 1. Estimate the length of the product
  - 10,000 delivered source instructions (10 KDSI)

- Step 2. Estimate the product development mode
  - Complex ("embedded") mode

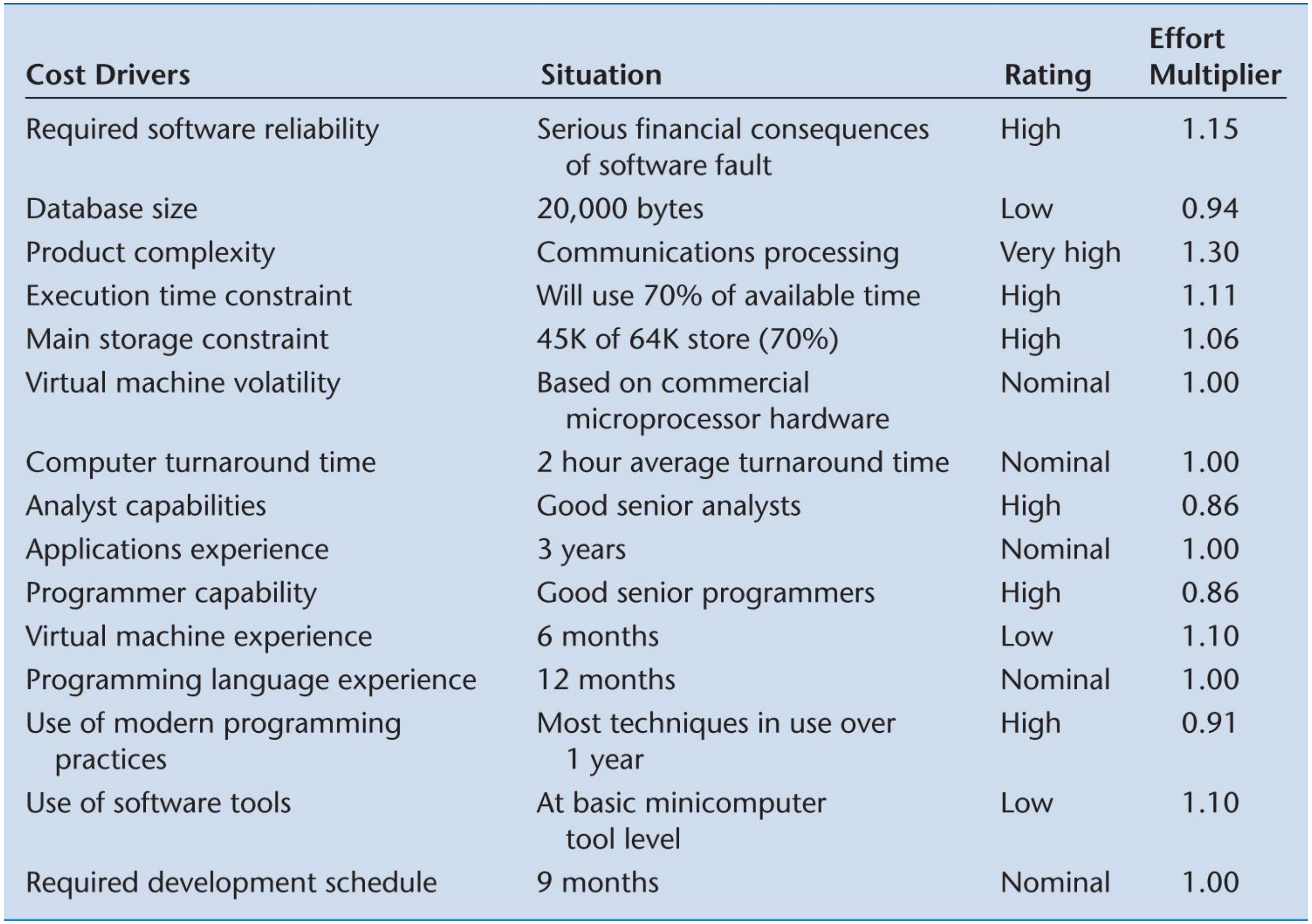
Intermediate COCOMO (contd)

- Step 3. Compute the nominal effort
  - Nominal effort = 2.8 ´ $(10)^{1.20}$ = 44 person-months

- Step 4. Multiply the nominal value by 15 software development cost multipliers
  - Product of effort multipliers = 1.35 (see table on next slide)
  - Estimated effort for project is therefore 1.35 ´ 44 = 59 person-months

Intermediate COCOMO (contd)

- Software development effort multipliers



Cost Drivers	Situation	Rating	Effort Multiplier
Required software reliability	Serious financial consequences of software fault	High	1.15
Database size	20,000 bytes	Low	0.94
Product complexity	Communications processing	Very high	1.30
Execution time constraint	Will use 70% of available time	High	1.11
Main storage constraint	45K of 64K store (70%)	High	1.06
Virtual machine volatility	Based on commercial microprocessor hardware	Nominal	1.00
Computer turnaround time	2 hour average turnaround time	Nominal	1.00
Analyst capabilities	Good senior analysts	High	0.86
Applications experience	3 years	Nominal	1.00
Programmer capability	Good senior programmers	High	0.86
Virtual machine experience	6 months	Low	1.10
Programming language experience	12 months	Nominal	1.00
Use of modern programming practices	Most techniques in use over 1 year	High	0.91
Use of software tools	At basic minicomputer tool level	Low	1.10
Required development schedule	9 months	Nominal	1.00

Figure 9.7

Intermediate COCOMO (contd)

- Estimated effort for project (59 person-months) is used as input for additional formulas for
  - Dollar costs
  - Development schedules
  - Phase and activity distributions
  - Computer costs
  - Annual maintenance costs
  - Related items

Intermediate COCOMO (contd)

- Intermediate COCOMO has been validated with respect to a broad sample

- Actual values are within 20% of predicted values about 68% of the time
  - Intermediate COCOMO was the most accurate estimation method of its time

- Major problem
  - If the estimate of the number of lines of codes of the target product is incorrect, then everything is incorrect

9.2.4 COCOMO II

- 1995 extension to 1981 COCOMO that incorporates
  - Object orientation
  - Modern life-cycle models
  - Rapid prototyping
  - Fourth-generation languages
  - COTS software

- COCOMO II is far more complex than the first version

COCOMO II (contd)

- There are three different models
  - Application composition model for the early phases
    - Based on feature points (similar to function points)
  - Early design model
    - Based on function points
  - Post-architecture model
    - Based on function points or KDSI

COCOMO II (contd)

- The underlying COCOMO effort model is

$$\text{effort} = a \times (\text{size})^b$$

  - Intermediate COCOMO
    - Three values for (*a*, *b*)
  - COCOMO II
    - *b* varies depending on the values of certain parameters
- COCOMO II supports reuse

COCOMO II (contd)

- COCOMO II has 17 multiplicative cost drivers (was 15)
  - Seven are new
- It is too soon for results regarding
  - The accuracy of COCOMO II
  - The extent of improvement (if any) over Intermediate COCOMO

9.2.5 Tracking Duration and Cost Estimates

- Whatever estimation method used, careful tracking is vital

9.3 Components of a Software Project Management Plan

- The work to be done
- The resources with which to do it
- The money to pay for it

Resources

- Resources needed for software development:
  - People
  - Hardware
  - Support software

Use of Resources Varies with Time

- Rayleigh curves accurately depict resource consumption

- The entire software development plan must be a function of time

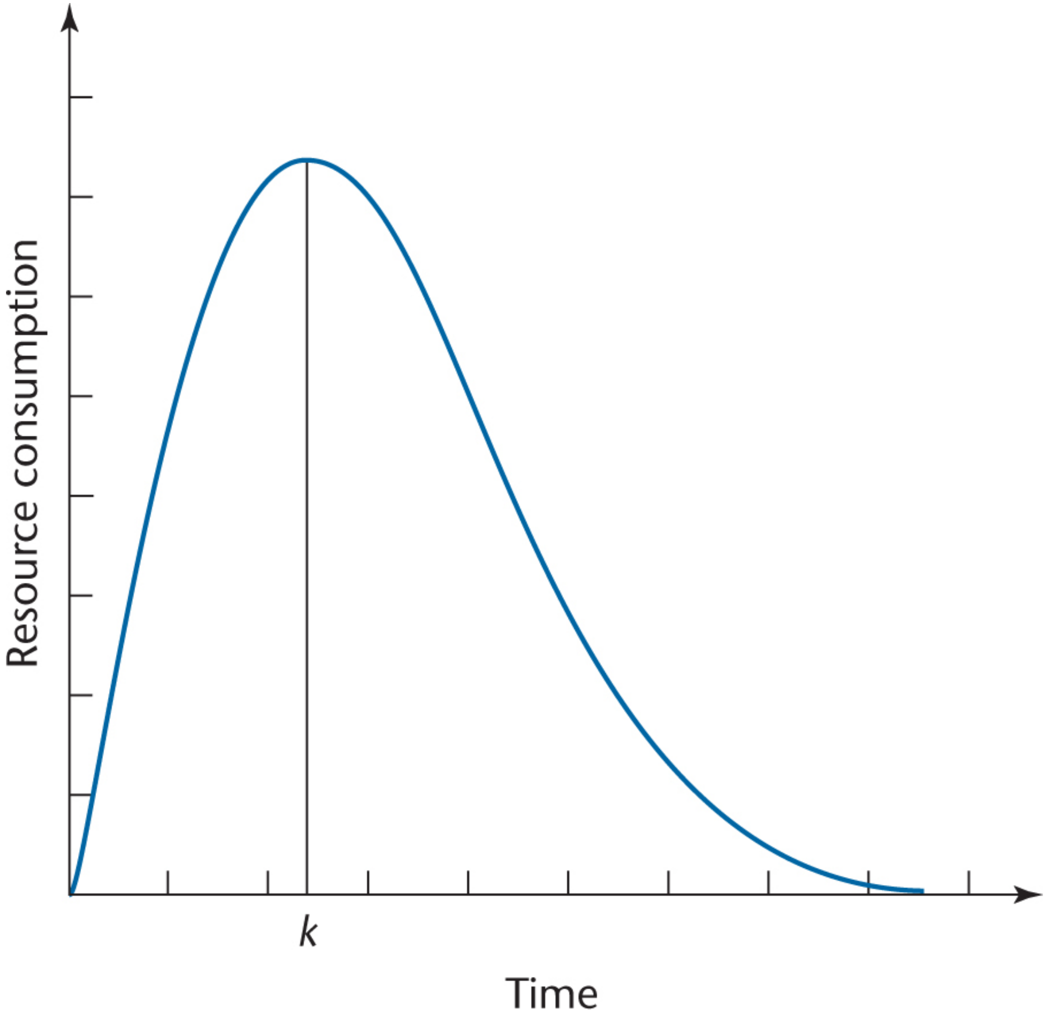


Figure 9.8

Work Categories

- Project function
  - Work carried on throughout the project
  - Examples:
    - Project management
    - Quality control

Work Categories

- Activity
  - Work that relates to a specific phase
  - A major unit of work,
  - With precise beginning and ending dates,
  - That consumes *resources*, and
  - Results in *work products* like the budget, design, schedules, source code, or users’ manual

Work Categories (contd)

- Task
  - An activity comprises a set of *tasks* (the smallest unit of work subject to management accountability)

Completion of Work Products

- *Milestone*: The date on which the work product is to be completed
- It must first pass *reviews* performed by
  - Fellow team members
  - Management
  - The client
- Once the work product has been reviewed and agreed upon, it becomes a *baseline*

Work Package

- Work product, *plus*
  - Staffing requirements
  - Duration
  - Resources
  - The name of the responsible individual
  - Acceptance criteria for the work product
  - The detailed budget as a function of time, allocated to
    - Project functions
    - Activities

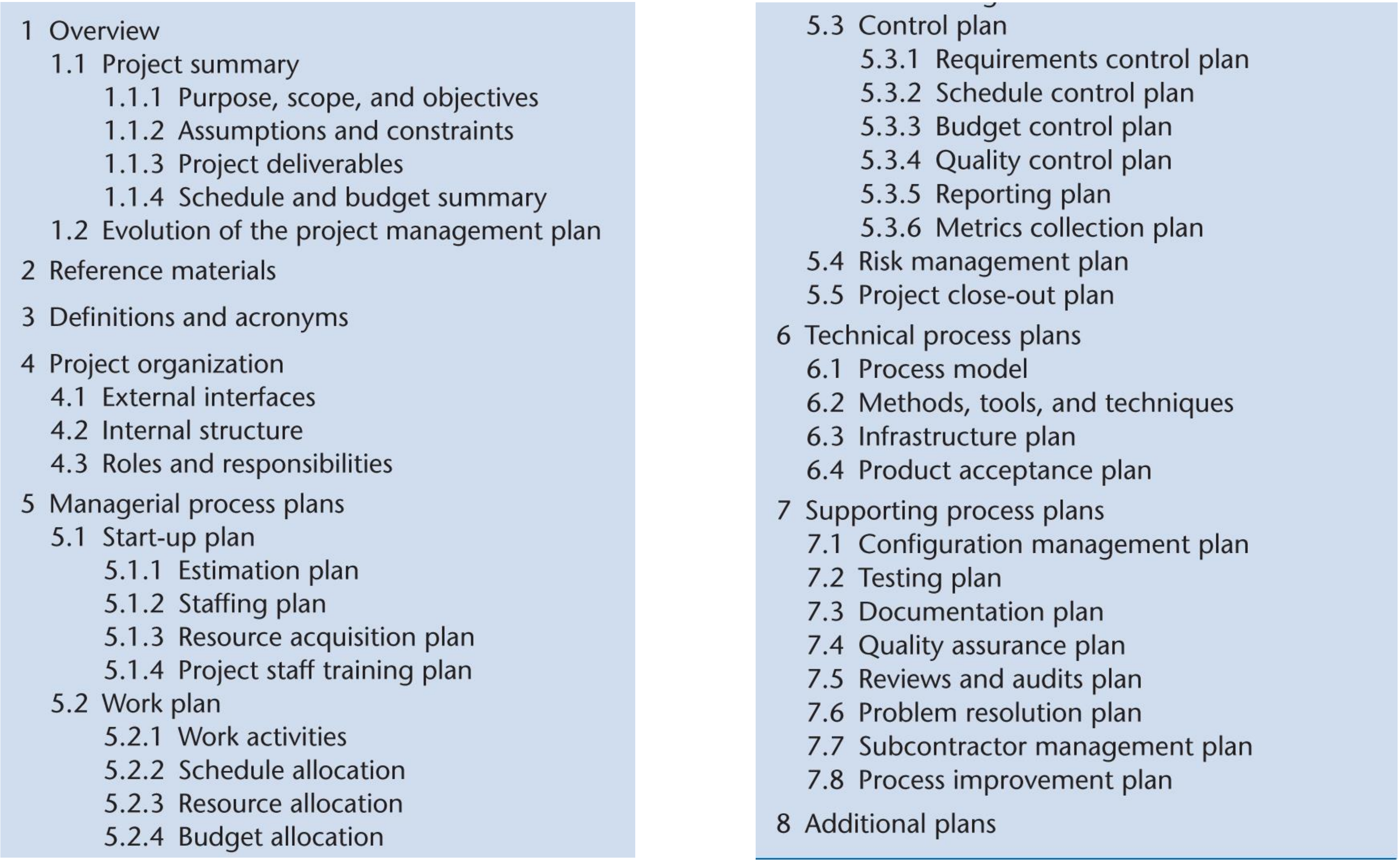
9.4 Software Project Management Plan Framework

- There are many ways to construct an SPMP
- One of the best is IEEE Standard 1058.1
  - The standard is widely accepted
  - It is designed for use with all types of software products
  - It supports process improvement
    - Many sections reflect CMM key process areas
  - It is ideal for the Unified Process
    - There are sections for requirements control and risk management

Software Project Management Plan Framework (contd)

- Some of the sections are inapplicable to small-scale software
  - Example: Subcontractor management plan

IEEE Software Project Management Plan



- 1 Overview
  - 1.1 Project summary
    - 1.1.1 Purpose, scope, and objectives
    - 1.1.2 Assumptions and constraints
    - 1.1.3 Project deliverables
    - 1.1.4 Schedule and budget summary
  - 1.2 Evolution of the project management plan
- 2 Reference materials
- 3 Definitions and acronyms
- 4 Project organization
  - 4.1 External interfaces
  - 4.2 Internal structure
  - 4.3 Roles and responsibilities
- 5 Managerial process plans
  - 5.1 Start-up plan
    - 5.1.1 Estimation plan
    - 5.1.2 Staffing plan
    - 5.1.3 Resource acquisition plan
    - 5.1.4 Project staff training plan
  - 5.2 Work plan
    - 5.2.1 Work activities
    - 5.2.2 Schedule allocation
    - 5.2.3 Resource allocation
    - 5.2.4 Budget allocation
  - 5.3 Control plan
    - 5.3.1 Requirements control plan
    - 5.3.2 Schedule control plan
    - 5.3.3 Budget control plan
    - 5.3.4 Quality control plan
    - 5.3.5 Reporting plan
    - 5.3.6 Metrics collection plan
  - 5.4 Risk management plan
  - 5.5 Project close-out plan
- 6 Technical process plans
  - 6.1 Process model
  - 6.2 Methods, tools, and techniques
  - 6.3 Infrastructure plan
  - 6.4 Product acceptance plan
- 7 Supporting process plans
  - 7.1 Configuration management plan
  - 7.2 Testing plan
  - 7.3 Documentation plan
  - 7.4 Quality assurance plan
  - 7.5 Reviews and audits plan
  - 7.6 Problem resolution plan
  - 7.7 Subcontractor management plan
  - 7.8 Process improvement plan
- 8 Additional plans

Figure 9.9

9.6 Planning Testing

- The SPMP must explicitly state what testing is to be done
- Traceability is essential
- All black box test cases must be drawn up as soon as possible after the specifications are complete

9.7 Planning Object-Oriented Projects

- An object-oriented product consists of largely independent pieces

- Consequently, planning is somewhat easier

- The whole is more than the sum of its parts

- We can use COCOMO II (or modify Intermediate COCOMO estimators)

Planning of Object-Oriented Projects (contd)

- However, reuse induces errors in cost and duration estimates
  - Reuse of existing components during development
  - Production of components for future reuse

- These work in opposite directions

- Newer data: The savings outweigh the costs

9.8 Training Requirements

- “We don’t need to worry about training until the product is finished, and then we can train the user”

- Training is generally needed by the members of the development group, starting with training in software planning

- A new software development method necessitates training for every member of the group

Training Requirements (contd)

- Introduction of hardware or software tools of any sort necessitates training

- Programmers may need training in the operating system and/or implementation language

- Documentation preparation training may be needed

- Computer operators require training

9.9 Documentation Standards

- How much documentation is generated by a product?
  - IBM internal commercial product (50 KDSI)
    - 28 pages of documentation per KDSI
  - Commercial software product of the same size
    - 66 pages per KDSI
  - IMS/360 Version 2.3 (about 166 KDSI)
    - 157 pages of documentation per KDSI
  - [TRW] For every 100 hours spent on coding activities, 150–200 hours were spent on documentation-related activities

Types of Documentation

- Planning
- Control
- Financial
- Technical
- Source code
- Comments within source code

Documentation Standards

- Reduce misunderstandings between team members
- Aid SQA
- Only new employees have to learn the standards
- Standards assist maintenance programmers
- Standardization is important for user manuals

Documentation Standards (contd)

- As part of the planning process
  - Standards must be set up for all documentation

- In a very real sense, the product *is* the documentation

9.10 CASE Tools for Planning and Estimating

- It is essential to have
  - A word processor; and
  - A spreadsheet
- Tool that automate intermediate COCOMO and COCOMO II are available
- Management tools assist with planning and monitoring
  - MacProject
  - Microsoft Project

9.11 Testing the Software Project Management Plan

- We must check the SPMP as a whole
  - Paying particular attention to the duration and cost estimates