

UNIT - I

Conventional Software Management: The waterfall model, conventional software Management performance.

Evolution of Software Economics: Software Economics, pragmatic software cost estimation

1. Conventional software management

Conventional software management practices are sound in theory, but practice is still tied to archaic (outdated) technology and techniques.

Conventional software economics provides a benchmark of performance for conventional software management principles.

The **best** thing about software is its **flexibility**: It can be programmed to do almost anything.

The **worst** thing about software is also its **flexibility**: The "almost anything" characteristic has made it difficult to plan, monitor, and control software development.

Three important analyses of the state of the software engineering industry are

1. Software development is still highly unpredictable. Only about **10%** of software projects are delivered **successfully** within initial budget and schedule estimates.
2. Management discipline is more of a discriminator in success or failure than are technology advances.
3. The level of software scrap and rework is indicative of an immature process.

All three analyses reached the same general conclusion: The success rate for software projects is very low.

The three analyses provide a good introduction to the magnitude of the software problem and the current norms for conventional software management performance.

1.1 THE WATERFALL MODEL

Most software engineering texts present the waterfall model as the source of the "conventional" software process.

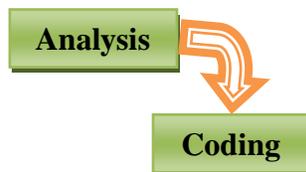
1.1.1 IN THEORY

It provides an insightful and concise summary of conventional software management

Three main primary points are

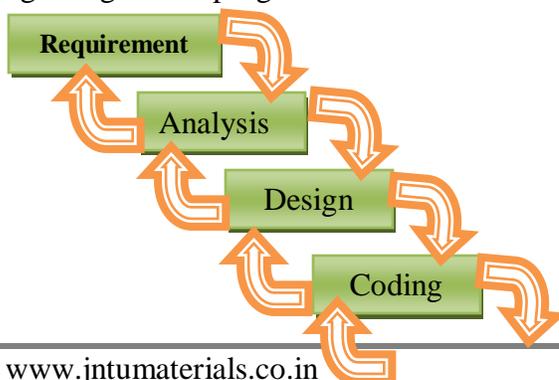
1. There are two essential steps common to the development of computer programs: **analysis** and **coding**.

Waterfall Model part 1: The two basic steps to building a program.



Analysis and coding both involve creative work that directly contributes to the usefulness of the end product.

2. In order to manage and control all of the intellectual freedom associated with software development, one must introduce several other "overhead" steps, including system requirements definition, software requirements definition, program design, and testing. These steps supplement the analysis and coding steps. Below Figure illustrates the resulting project profile and the basic steps in developing a large-scale program.





3. The basic framework described in the waterfall model is risky and invites failure. The testing phase that occurs at the end of the development cycle is the first event for which timing, storage, input/output transfers, etc., are experienced as distinguished from analyzed. The resulting design changes are likely to be so disruptive that the software requirements upon which the design is based are likely violated. Either the requirements must be modified or a substantial design change is warranted.

Five necessary improvements for waterfall model are:-

- 1. Program design comes first.** Insert a preliminary program design phase between the software requirements generation phase and the analysis phase. **By this technique, the program designer assures that the software will not fail because of storage, timing, and data flux (continuous change).** As analysis proceeds in the succeeding phase, the program designer must impose on the analyst the storage, timing, and operational constraints in such a way that he senses the consequences. If the total resources to be applied are insufficient or if the embryonic (in an early stage of development) operational design is wrong, it will be recognized at this early stage and the iteration with requirements and preliminary design can be redone before final design, coding, and test commences. How is this program design procedure implemented?

The following steps are required:

Begin the design process with program **designers**, not analysts or programmers.

Design, define, and allocate the data processing modes even at the risk of being wrong. Allocate processing functions, design the database, allocate execution time, define interfaces and processing modes with the operating system, describe input and output processing, and define preliminary operating procedures.

Write an overview document that is understandable, informative, and current so that every worker on the project can gain an elemental understanding of the system.

- 2. Document the design.** The amount of documentation required on most software programs is quite a lot, certainly much more than most programmers, analysts, or program designers are willing to do if left to their own devices. Why do we need so much documentation? **(1)** Each designer must communicate with interfacing designers, managers, and possibly customers. **(2)** During early phases, the documentation is the design. **(3)** The real monetary value of documentation is to support later modifications by a separate test team, a separate maintenance team, and operations personnel who are not software literate.

- 3. Do it twice.** If a computer program is being developed for the first time, arrange matters so that the version finally delivered to the customer for operational deployment is actually the second version insofar as critical design/operations are concerned. Note that this is simply the entire process done in miniature, to a time scale that is relatively small with respect to the overall effort. In the first version, the team must have a special broad competence where they can quickly sense trouble spots in the design, model them, model alternatives, forget the straightforward aspects of the design that aren't worth studying at this early point, and, finally, arrive at an error-free program.

- 4. Plan, control, and monitor testing.** Without question, the biggest user of project resources—manpower, computer time, and/or management judgment—is the test phase. This is the phase of greatest risk in terms of cost and schedule. It occurs at the latest point in the schedule, when backup alternatives are least available, if

at all. The previous three recommendations were all aimed at uncovering and solving problems before entering the test phase. However, even after doing these things, there is still a test phase and there are still important things to be done, including: (1) employ a team of test specialists who were not responsible for the original design; (2) employ visual inspections to spot the obvious errors like dropped minus signs, missing factors of two, jumps to wrong addresses (do not use the computer to detect this kind of thing, it is too expensive); (3) test every logic path; (4) employ the final checkout on the target computer.

5. Involve the customer. It is important to involve the customer in a formal way so that he has committed himself at earlier points before final delivery. There are three points following requirements definition where the insight, judgment, and commitment of the customer can bolster the development effort. These include a "preliminary software review" following the preliminary program design step, a sequence of "critical software design reviews" during program design, and a "final software acceptance review".

1.1.2 IN PRACTICE

Some software projects still practice the conventional software management approach.

It is useful to summarize the characteristics of the conventional process as it has typically been applied, which is not necessarily as it was intended. Projects destined for trouble frequently exhibit the following symptoms:

- Protracted integration and late design breakage.
- Late risk resolution.
- Requirements-driven functional decomposition.
- Adversarial (conflict or opposition) stakeholder relationships.
- Focus on documents and review meetings.

Protracted Integration and Late Design Breakage

For a typical development project that used a waterfall model management process, Figure 1-2 illustrates development progress versus time. Progress is defined as percent coded, that is, demonstrable in its target form.

The following sequence was common:

- Early success via paper designs and thorough (often *too* thorough) briefings.
- Commitment to code late in the life cycle.
- Integration nightmares (unpleasant experience) due to unforeseen implementation issues and interface ambiguities.
- Heavy budget and schedule pressure to get the system working.
- Late shoe-horning of no optimal fixes, with no time for redesign.
- A very fragile, unmentionable product delivered late.

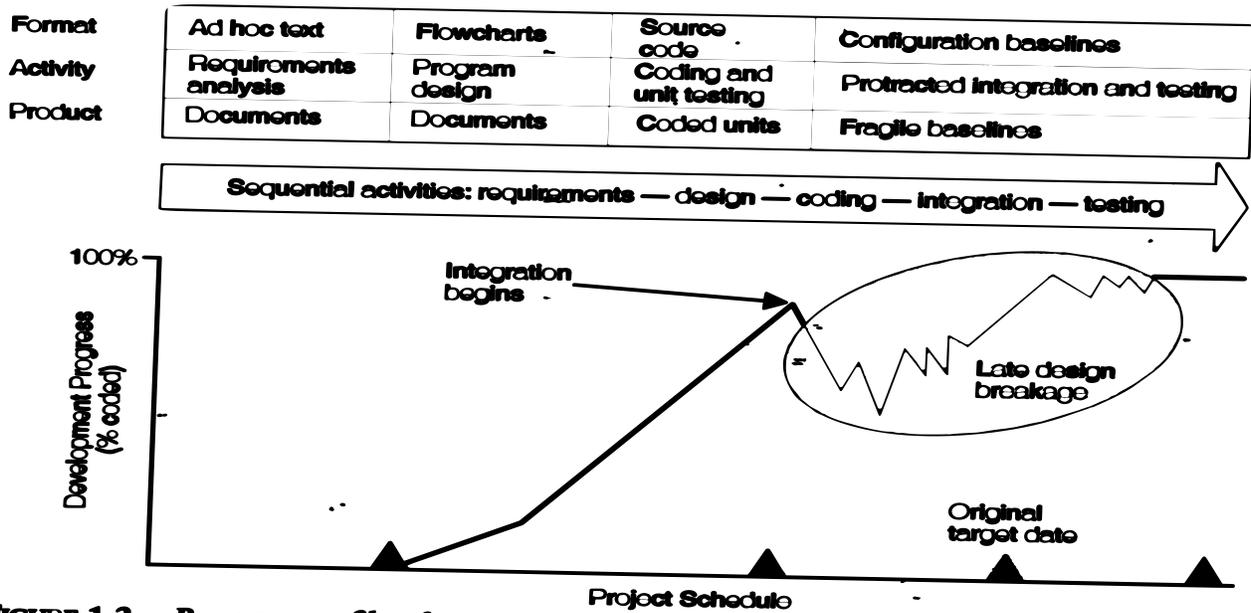


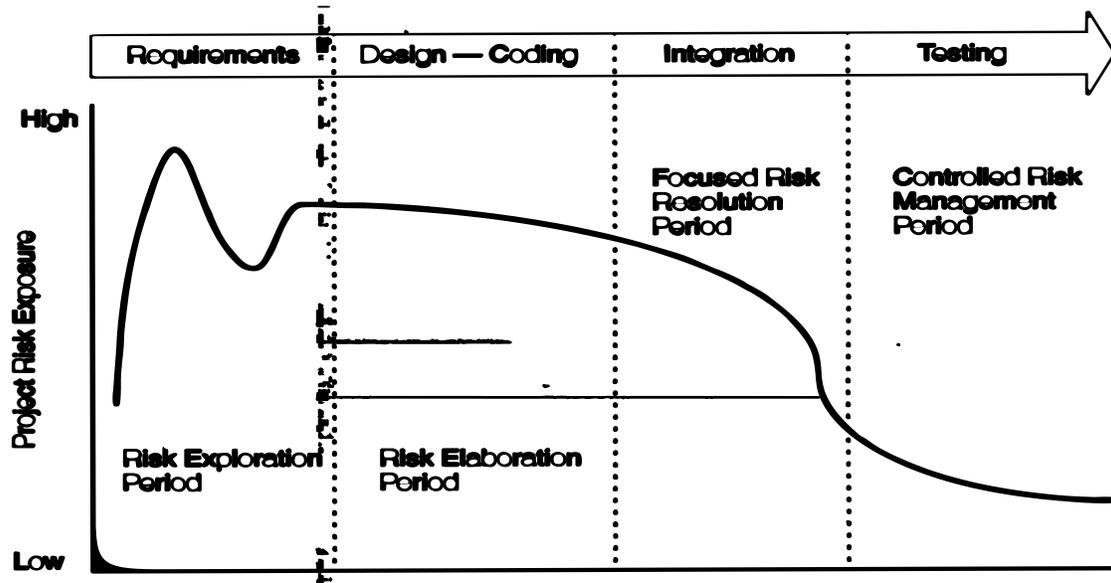
FIGURE 1-2. Progress profile of a conventional software project

In the conventional model, the entire system was designed on paper, then implemented all at once, then integrated. Table 1-1 provides a typical profile of cost expenditures across the spectrum of software activities.

TABLE 1-1. Expenditures by activity for a conventional software project

ACTIVITY	COST
Management	5%
Requirements	5%
Design	10%
Code and unit testing	30%
Integration and test	40%
Deployment	5%
Environment	5%
Total	100%

Late risk resolution A serious issue associated with the waterfall lifecycle was the lack of early risk resolution. Figure 1.3 illustrates a typical risk profile for conventional waterfall model projects. It includes four distinct periods of risk exposure, where risk is defined as the probability of missing a cost, schedule, feature, or quality goal. Early in the life cycle, as the requirements were being specified, the actual risk exposure was highly unpredictable.



Requirements-Driven Functional Decomposition: This approach depends on specifying requirements completely and unambiguously before other development activities begin. It naively treats all requirements as equally important, and depends on those requirements remaining constant over the software development life cycle. These conditions rarely occur in the real world. Specification of requirements is a difficult and important part of the software development process.

Another property of the conventional approach is that the requirements were typically specified in a functional manner. Built into the classic waterfall process was the fundamental assumption that the software itself was decomposed into functions; requirements were then allocated to the resulting components. This decomposition was often very different from a decomposition based on object-oriented design and the use of existing components. Figure 1-4 illustrates the result of requirements-driven approaches: a software structure that is organized around the requirements specification structure.

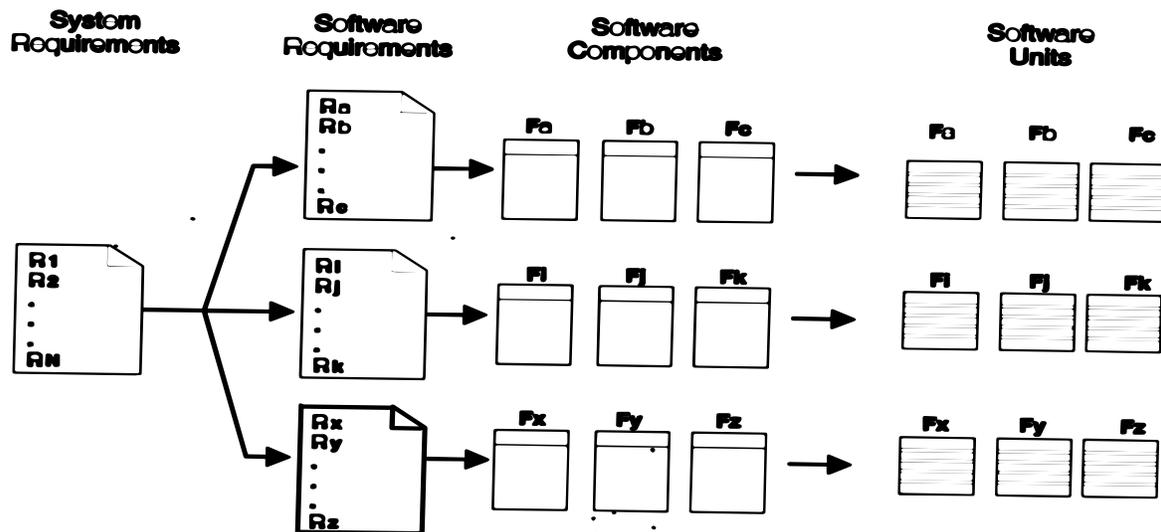


FIGURE 1-4: *Suboptimal software component organization resulting from a requirements-driven approach*

Adversarial Stakeholder Relationships:

The conventional process tended to result in adversarial stakeholder relationships, in large part because of the difficulties of requirements specification and the exchange of information solely through paper documents that captured engineering information in ad hoc formats.

The following sequence of events was typical for most contractual software efforts:

1. The contractor prepared a draft contract-deliverable document that captured an intermediate artifact and delivered it to the customer for approval.
2. The customer was expected to provide comments (typically within 15 to 30 days).
3. The contractor incorporated these comments and submitted (typically within 15 to 30 days) a final version for approval.

This one-shot review process encouraged high levels of sensitivity on the part of customers and contractors.

Focus on Documents and Review Meetings:

The conventional process focused on producing various documents that attempted to describe the software product, with insufficient focus on producing tangible increments of the products themselves. Contractors were driven to produce literally tons of paper to meet milestones and demonstrate progress to stakeholders, rather than spend their energy on tasks that would reduce risk and produce quality software. Typically, presenters and the audience reviewed the simple things that they understood rather than the complex and important issues. Most design reviews therefore resulted in low engineering value and high cost in terms of the effort and schedule involved in their preparation and conduct. They presented merely a facade of progress.

Table 1-2 summarizes the results of a typical design review.

TABLE 1-2. Results of conventional software project design reviews

APPARENT RESULTS	REAL RESULTS
Big briefing to a diverse audience	Only a small percentage of the audience understands the software. Briefings and documents expose few of the important assets and risks of complex software systems.
A design that appears to be compliant	There is no tangible evidence of compliance. Compliance with ambiguous requirements is of little value.
Coverage of requirements (typically hundreds)	Few (tens) are design drivers. Dealing with all requirements dilutes the focus on the critical drivers.
A design considered "innocent until proven guilty"	The design is always guilty. Design flaws are exposed later in the life cycle.

1.2 CONVENTIONAL SOFTWARE MANAGEMENT PERFORMANCE

Barry Boehm's "Industrial Software Metrics Top 10 List" is a good, objective characterization of the state of software development.

1. Finding and fixing a software problem after delivery **costs 100** times more than finding and fixing the problem in early design phases.
2. You can compress software development schedules **25%** of nominal, but no more.

3. For every **\$1** you spend on development, you will spend **\$2** on maintenance.
4. Software development and maintenance costs are primarily a function of the number of source lines of code.
5. Variations among people account for the **biggest** differences in software productivity.
6. The overall ratio of software to hardware costs is still growing. In 1955 it was **15:85**; in 1985, **85:15**.
7. Only about **15%** of software development effort is devoted to programming.
8. Software systems and products typically cost 3 times as much per SLOC as individual software programs. Software-system products (i.e., system of systems) cost 9 times as much.
9. Walkthroughs catch **60%** of the errors
10. **80%** of the contribution comes from **20%** of the contributors.



2. Evolution of Software Economics

2.1 SOFTWARE ECONOMICS

Most software cost models can be abstracted into a function of five basic parameters: **size, process, personnel, environment, and required quality.**

1. The *size* of the end product (in human-generated components), which is typically quantified in terms of the number of source instructions or the number of function points required to develop the required functionality
2. The *process* used to produce the end product, in particular the ability of the process to avoid non-value-adding activities (rework, bureaucratic delays, communications overhead)
3. The capabilities of software engineering *personnel*, and particularly their experience with the computer science issues and the applications domain issues of the project
4. The *environment*, which is made up of the tools and techniques available to support efficient software development and to automate the process
5. The required *quality* of the product, including its features, performance, reliability, and adaptability

The relationships among these parameters and the estimated cost can be written as follows:

$$\text{Effort} = (\text{Personnel}) (\text{Environment}) (\text{Quality}) (\text{Size}^{\text{process}})$$

One important aspect of software economics (as represented within today's software cost models) is that the relationship between effort and size exhibits a diseconomy of scale. The diseconomy of scale of software development is a result of the process exponent being greater than 1.0. Contrary to most manufacturing

processes, the more software you build, the more expensive it is per unit item.

Figure 2-1 shows three generations of basic technology advancement in tools, components, and processes. The required levels of quality and personnel are assumed to be constant. The ordinate of the graph refers to software unit costs (pick your favorite: per SLOC, per function point, per component) realized by an organization.

The three generations of software development are defined as follows:

- 1) **Conventional:** 1960s and 1970s, craftsmanship. Organizations used custom tools, custom processes, and virtually all custom components built in primitive languages. Project performance was highly predictable in that cost, schedule, and quality objectives were almost always underachieved.
- 2) **Transition:** 1980s and 1990s, software engineering. Organizations used more-repeatable processes and off-the-shelf tools, and mostly (>70%) custom components built in higher level languages. Some of the components (<30%) were available as commercial products, including the operating system, database management system, networking, and graphical user interface.
- 3) **Modern practices:** 2000 and later, software production. This book's philosophy is rooted in the use of managed and measured processes, integrated automation environments, and mostly (70%) off-the-shelf components. Perhaps as few as 30% of the components need to be custom built

Technologies for environment automation, size reduction, and process improvement are not independent of one another. In each new era, the key is complementary growth in all technologies. For example, the process advances could not be used successfully without new component technologies and increased tool automation.



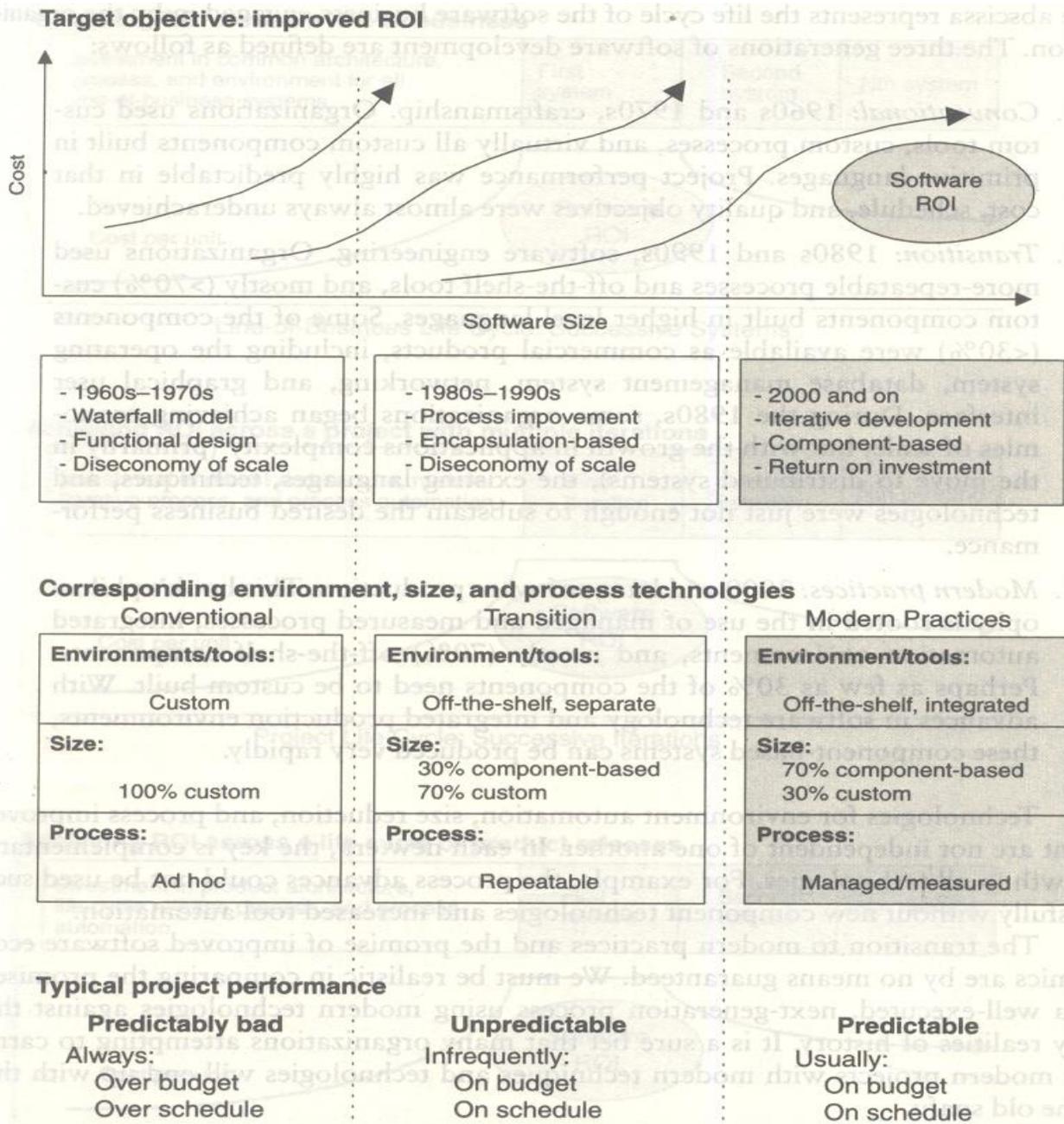
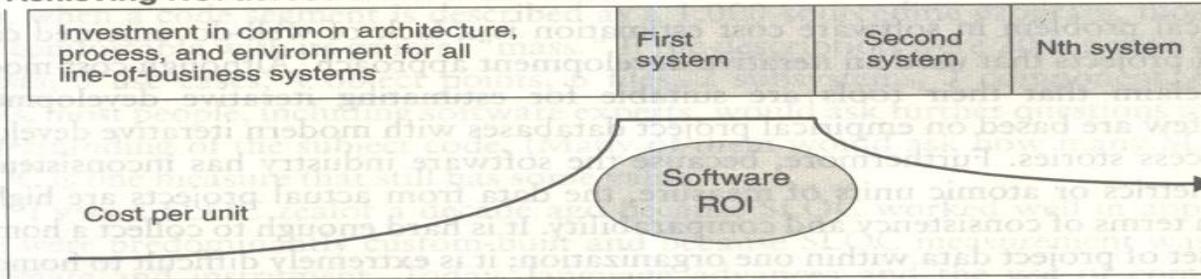


FIGURE 2-1. Three generations of software economics leading to the target objective

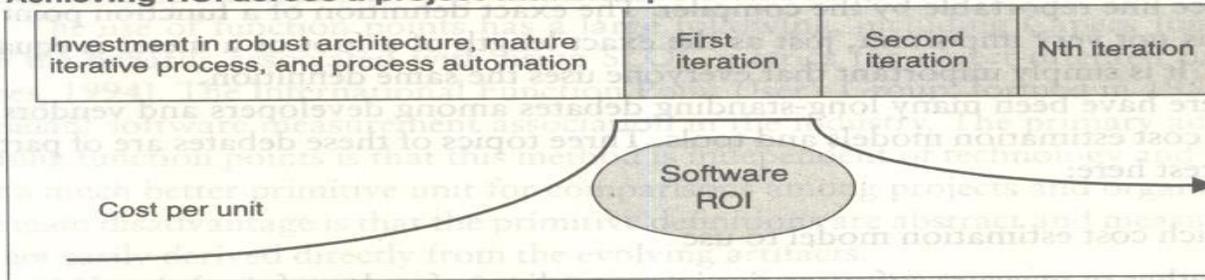
Organizations are achieving better economies of scale in successive technology eras—with very large projects (systems of systems), long-lived products, and lines of business comprising multiple similar projects. Figure 2-2 provides an overview of how a return on investment (ROI) profile can be achieved in subsequent efforts across life cycles of various domains.

Achieving ROI across a line of business



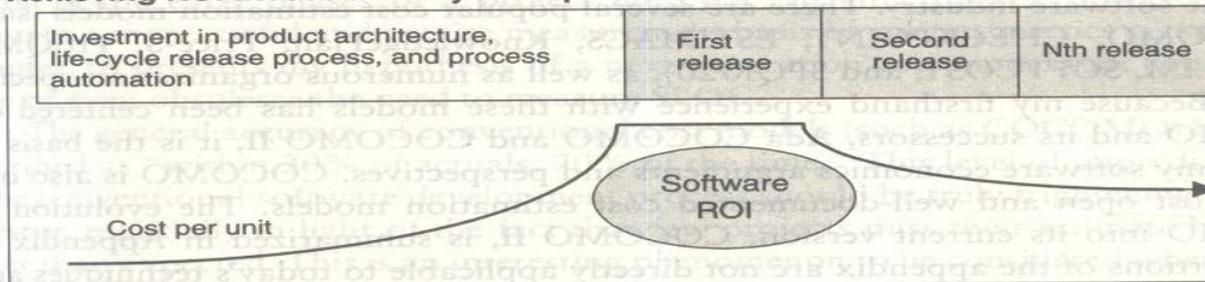
Line-of-Business Life Cycle: Successive Systems

Achieving ROI across a project with multiple iterations



Project Life Cycle: Successive Iterations

Achieving ROI across a life cycle of product releases



Product Life Cycle: Successive Releases

FIGURE 2-2. Return on investment in different domains

2.2 PRAGMATIC SOFTWARE COST ESTIMATION

One critical problem in software cost estimation is a lack of well-documented case studies of projects that used an iterative development approach. Software industry has inconsistently defined metrics or atomic units of measure, the data from actual projects are highly suspect in terms of consistency and comparability. It is hard enough to collect a homogeneous set of project data within one organization; it is extremely difficult to homogenize data across different organizations with different processes, languages, domains, and so on.

There have been many debates among developers and vendors of software cost estimation models and tools. Three topics of these debates are of particular interest here:

1. Which cost estimation model to use?
2. Whether to measure software size in source lines of code or function points.
3. What constitutes a good estimate?

There are several popular cost estimation models (such as COCOMO, CHECKPOINT, ESTIMACS, KnowledgePlan, Price-S, ProQMS, SEER, SLIM, SOFTCOST, and SPQR/20), CO COMO is also one of the most open and well-documented cost estimation models. The general accuracy of conventional cost models (such as COCOMO) has been described as "within 20% of actuals, 70% of the time."

Most real-world use of cost models is bottom-up (substantiating a target cost) rather than top-down (estimating the "should" cost). Figure 2-3 illustrates the predominant practice: The software project manager defines the target cost of the software, and then manipulates the parameters and sizing until the target cost can be justified. The rationale for the target cost maybe *to win a proposal, to solicit customer funding, to attain internal corporate funding, or to achieve some other goal.*

The process described in Figure 2-3 is not all bad. In fact, it is absolutely necessary to analyze the cost risks and understand the sensitivities and trade-offs objectively. It forces the software project manager to examine the risks associated with achieving the target costs and to discuss this information with other stakeholders.

A good software cost estimate has the following attributes:

- It is conceived and supported by the project manager, architecture team, development team, and test team accountable for performing the work.
- It is accepted by all stakeholders as ambitious but realizable.
- It is based on a well-defined software cost model with a credible basis.
- It is based on a database of relevant project experience that includes similar processes, similar technologies, similar environments, similar quality requirements, and similar people.
- It is defined in enough detail so that its key risk areas are understood and the probability of success is objectively assessed.

Extrapolating from a good estimate, an *ideal* estimate would be derived from a mature cost model with an experience base that reflects multiple similar projects done by the same team with the same mature processes and tools.

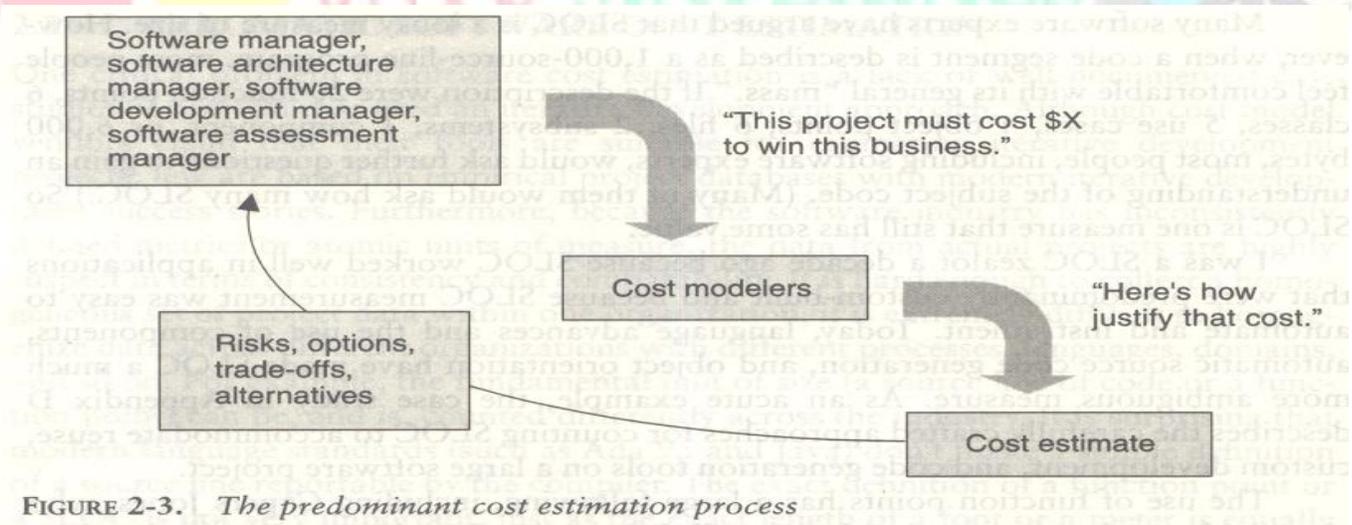


FIGURE 2-3. The predominant cost estimation process

===THE END===



UNIT – II

Improving Software Economics: Reducing Software product size, improving software processes, improving team effectiveness, improving automation, Achieving required quality, peer inspections.

The old way and the new: The principles of conventional software Engineering, principles of modern software management, transitioning to an iterative process.

3. Improving Software Economics

Five basic parameters of the software cost model are

- 1.Reducing the *size* or complexity of what needs to be developed.
2. Improving the development *process*.
3. Using more-skilled *personnel* and better teams (not necessarily the same thing).
4. Using better *environments* (tools to automate the process).
5. Trading off or backing off on *quality* thresholds.

These parameters are given in priority order for most software domains. Table 3-1 lists some of the technology developments, process improvement efforts, and management approaches targeted at improving the economics of software development and integration.

TABLE 3-1. Important trends in improving software economics

COST MODEL PARAMETERS	TRENDS
Size	Higher order languages (C++, Ada 95, Java, Visual Basic, etc.)
Abstraction and component-based development technologies	Object-oriented (analysis, design, programming)
	Reuse
	Commercial components
Process	Iterative development
Methods and techniques	Process maturity models
	Architecture-first development
	Acquisition reform
Personnel	Training and personnel skill development
People factors	Teamwork
	Win-win cultures
Environment	Integrated tools (visual modeling, compiler, editor, debugger, change management, etc.)
Automation technologies and tools	Open systems
	Hardware platform performance
	Automation of coding, documents, testing, analyses
Quality	Hardware platform performance
Performance, reliability, accuracy	Demonstration-based assessment
	Statistical quality control

3.1 REDUCING SOFTWARE PRODUCT SIZE

The most significant way to improve affordability and return on investment (ROI) is usually to produce a product that achieves the design goals with the minimum amount of human-generated source material. **Component-based development** is introduced as the general term for reducing the "source" language size to achieve a software solution.

Reuse, object-oriented technology, automatic code production, and higher order programming languages are all focused on achieving a given system with fewer lines of human-specified source directives (statements).

size reduction is the primary motivation behind improvements in higher order languages (such as C++, Ada 95, Java, Visual Basic), automatic code generators (CASE tools, visual modeling tools, GUI builders), reuse of **commercial components** (operating systems, windowing environments, database management systems,

middleware, networks), and object-oriented technologies (Unified Modeling Language, visual modeling tools, architecture frameworks).

The reduction is defined in terms of human-generated source material. In general, when size-reducing technologies are used, they reduce the number of human-generated source lines.

3.1.1 LANGUAGES

Universal function points (UFPs¹) are useful estimators for language-independent, early life-cycle estimates. The basic units of function points are external user inputs, external outputs, internal logical data groups, external data interfaces, and external inquiries. SLOC metrics are useful estimators for software after a candidate solution is formulated and an implementation language is known. Substantial data have been documented relating SLOC to function points. Some of these results are shown in Table 3-2.

Languages expressiveness of some of today's popular languages

LANGUAGES	SLOC per UFP
Assembly	320
C	128
FORTAN77	105
COBOL85	91
Ada83	71
C++	56
Ada95	55
Java	55
Visual Basic	35

Table 3-2

3.1.2 OBJECT-ORIENTED METHODS AND VISUAL MODELING

Object-oriented technology is not germane to most of the software management topics discussed here, and books on object-oriented technology abound. Object-oriented programming languages appear to benefit both software productivity and software quality. The fundamental impact of object-oriented technology is in reducing the overall size of what needs to be developed.

People like drawing pictures to explain something to others or to themselves. When they do it for software system design, they call these pictures diagrams or diagrammatic models and the very notation for them a modeling language.

These are interesting examples of the interrelationships among the dimensions of improving software economics.

1. An object-oriented model of the problem and its solution encourages a common vocabulary between the end users of a system and its developers, thus creating a shared understanding of the problem being solved.
2. The use of continuous integration creates opportunities to recognize risk early and make incremental corrections without destabilizing the entire development effort.

¹ Function point metrics provide a standardized method for measuring the various functions of a software application. The basic units of function points are external user inputs, external outputs, internal logical data groups, external data interfaces, and external inquiries.

3. An object-oriented architecture provides a clear separation of concerns among disparate elements of a system, creating firewalls that prevent a change in one part of the system from rending the fabric of the entire architecture.

Booch also summarized five characteristics of a successful object-oriented project.

1. A ruthless focus on the development of a system that provides a well understood collection of essential minimal characteristics.
2. The existence of a culture that is centered on results, encourages communication, and yet is not afraid to fail.
3. The effective use of object-oriented modeling.
4. The existence of a strong architectural vision.
5. The application of a well-managed iterative and incremental development life cycle.

3.1.3 REUSE

Reusing existing components and building reusable components have been natural software engineering activities since the earliest improvements in programming languages. With reuse in order to minimize development costs while achieving all the other required attributes of performance, feature set, and quality. Try to treat reuse as a mundane part of achieving a return on investment.

Most truly reusable components of value are transitioned to commercial products supported by organizations with the following characteristics:

- They have an economic motivation for continued support.
- They take ownership of improving product quality, adding new features, and transitioning to new technologies.
- They have a sufficiently broad customer base to be profitable.

The cost of developing a reusable component is not trivial. Figure 3-1 examines the economic trade-offs. The steep initial curve illustrates the economic obstacle to developing reusable components.

Reuse is an important discipline that has an impact on the efficiency of all workflows and the quality of most artifacts.

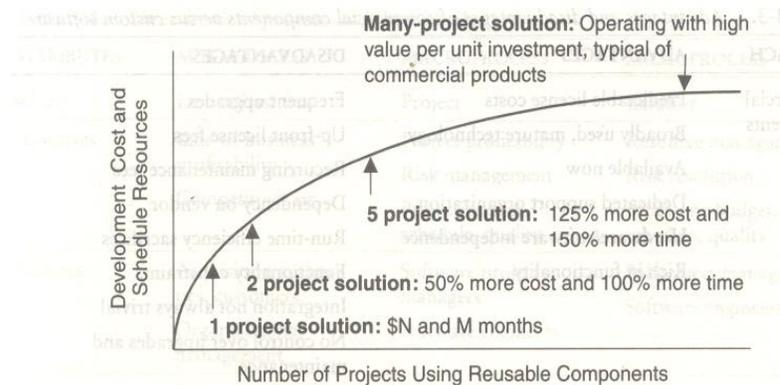


FIGURE 3-1. Cost and schedule investments necessary to achieve reusable components

3.1.4 COMMERCIAL COMPONENTS

A common approach being pursued today in many domains is to maximize integration of commercial components and off-the-shelf products. While the use of commercial components is certainly desirable as a means of reducing custom development, it has not proven to be straightforward in practice. Table 3-3 identifies some of the advantages and disadvantages of using commercial components.

TABLE 3-3. Advantages and disadvantages of commercial components versus custom software

APPROACH	ADVANTAGES	DISADVANTAGES
Commercial components	Predictable license costs	Frequent upgrades
	Broadly used, mature technology	Up-front license fees
	Available now	Recurring maintenance fees
	Dedicated support organization	Dependency on vendor
	Hardware/software independence	Run-time efficiency sacrifices
	Rich in functionality	Functionality constraints
		Integration not always trivial
		No control over upgrades and maintenance
		Unnecessary features that consume extra resources
		Often inadequate reliability and stability
	Multiple-vendor incompatibilities	
Custom development	Complete change freedom	Expensive, unpredictable development
	Smaller, often simpler implementations	Unpredictable availability date
	Often better performance	Undefined maintenance model
	Control of development and enhancement	Often immature and fragile
		Single-platform dependency
	Drain on expert resources	

3.2 IMPROVING SOFTWARE PROCESSES

Process is an overloaded term. Three distinct process perspectives are.

- **Metaprocess:** an organization's policies, procedures, and practices for pursuing a software-intensive line of business. The focus of this process is on organizational economics, long-term strategies, and software ROI.
- **Macroprocess:** a project's policies, procedures, and practices for producing a complete software product within certain cost, schedule, and quality constraints. The focus of the macro process is on creating an adequate instance of the Meta process for a specific set of constraints.
- **Microprocess:** a project team's policies, procedures, and practices for achieving an artifact of the software process. The focus of the micro process is on achieving an intermediate product baseline with adequate quality and adequate functionality as economically and rapidly as practical.

Although these three levels of process overlap somewhat, they have different objectives, audiences, metrics, concerns, and time scales as shown in Table 3-4

TABLE 3-4. Three levels of process and their attributes

ATTRIBUTES	METAPROCESS	MACROPROCESS	MICROPROCESS
Subject	Line of business	Project	Iteration
Objectives	Line-of-business profitability	Project profitability	Resource management
	Competitiveness	Risk management	Risk resolution
Audience	Acquisition authorities, customers	Project budget, schedule, quality	Milestone budget, schedule, quality
	Organizational management	Software project managers	Subproject managers
Metrics	Project predictability	Software engineers	Software engineers
	Revenue, market share	On budget, on schedule	On budget, on schedule
		Major milestone success	Major milestone progress
Concerns	Bureaucracy vs. standardization	Project scrap and rework	Release/iteration scrap and rework
		Quality vs. financial performance	Content vs. schedule
Time scales	6 to 12 months	1 to many years	1 to 6 months

In a perfect software engineering world with an immaculate problem description, an obvious solution space, a development team of experienced geniuses, adequate resources, and stakeholders with common goals, we could execute a software development process in one iteration with almost no scrap and rework.

Because we work in an imperfect world, however, we need to manage engineering activities so that scrap and rework profiles do not have an impact on the win conditions of any stakeholder. This should be the underlying premise for most process improvements.

3.3 IMPROVING TEAM EFFECTIVENESS

Teamwork is much more important than the sum of the individuals. With software teams, a project manager needs to configure a balance of solid talent with highly skilled people in the leverage positions. Some maxims of team management include the following:

- A well-managed project can succeed with a nominal engineering team.
- A mismanaged project will almost never succeed, even with an expert team of engineers.
- A well-architected system can be built by a nominal team of software builders.
- A poorly architected system will flounder even with an expert team of builders.

Boehm five staffing principles are

1. The principle of top talent: Use better and fewer people
2. The principle of job matching: Fit the tasks to the skills and motivation of the people available.
3. The principle of career progression: An organization does best in the long run by helping its people to **self-actualize**.
4. The principle of team balance: Select people who will complement and harmonize with one another
5. The principle of phase-out: Keeping a misfit on the team doesn't benefit anyone

Software project managers need many leadership qualities in order to enhance team effectiveness. The following are some crucial attributes of successful software project managers that deserve much more attention:

1. **Hiring skills.** Few decisions are as important as hiring decisions. Placing the right person in the right job seems obvious but is surprisingly hard to achieve.
2. **Customer-interface skill.** Avoiding adversarial relationships among stakeholders is a prerequisite for success.

Decision-making skill. The jillion books written about management have failed to provide a clear definition of this attribute. We all know a good leader when we run into one, and decision-making skill seems obvious despite its intangible definition.

Team-building skill. Teamwork requires that a manager establish trust, motivate progress, exploit eccentric prima donnas, transition average people into top performers, eliminate misfits, and consolidate diverse opinions into a team direction.

Selling skill. Successful project managers must sell all stakeholders (including themselves) on decisions and priorities, sell candidates on job positions, sell changes to the status quo in the face of resistance, and sell achievements against objectives. In practice, selling requires continuous negotiation, compromise, and empathy

3.4 IMPROVING AUTOMATION THROUGH SOFTWARE ENVIRONMENTS

The tools and environment used in the software process generally have a linear effect on the productivity of the process. Planning tools, requirements management tools, visual modeling tools, compilers, editors, debuggers, quality assurance analysis tools, test tools, and user interfaces provide crucial automation support for evolving the software engineering artifacts. Above all, configuration management environments provide the foundation for executing and instrument the process. At first order, the isolated impact of tools and automation generally allows improvements of 20% to 40% in effort. However, tools and

environments must be viewed as the primary delivery vehicle for process automation and improvement, so their impact can be much higher.

Automation of the design process provides payback in quality, the ability to estimate costs and schedules, and overall productivity using a smaller team.

Round-trip engineering describe the key capability of environments that support iterative development. As we have moved into maintaining different information repositories for the engineering artifacts, we need automation support to ensure efficient and error-free transition of data from one artifact to another. *Forward engineering* is the automation of one engineering artifact from another, more abstract representation. For example, compilers and linkers have provided automated transition of source code into executable code.

Reverse engineering is the generation or modification of a more abstract representation from an existing artifact (for example, creating a .visual design model from a source code representation).

Economic improvements associated with tools and environments. It is common for tool vendors to make relatively accurate individual assessments of life-cycle activities to support claims about the potential economic impact of their tools. For example, it is easy to find statements such as the following from companies in a particular tool.

- Requirements analysis and evolution activities consume 40% of life-cycle costs.
- Software design activities have an impact on more than 50% of the resources.
- Coding and unit testing activities consume about 50% of software development effort and schedule.
- Test activities can consume as much as 50% of a project's resources.
- Configuration control and change management are critical activities that can consume as much as 25% of resources on a large-scale project.
- Documentation activities can consume more than 30% of project engineering resources.
- Project management, business administration, and progress assessment can consume as much as 30% of project budgets.

3.5 ACHIEVING REQUIRED QUALITY

Software best practices are derived from the development process and technologies. Table 3-5 summarizes some dimensions of quality improvement.

Key practices that improve overall software quality include the following:

- Focusing on driving requirements and critical use cases early in the life cycle, focusing on requirements completeness and traceability late in the life cycle, and focusing throughout the life cycle on a balance between requirements evolution, design evolution, and plan evolution
- Using metrics and indicators to measure the progress and quality of an architecture as it evolves from a high-level prototype into a fully compliant product
- Providing integrated life-cycle environments that support early and continuous configuration control, change management, rigorous design methods, document automation, and regression test automation
- Using visual modeling and higher level languages that support architectural control, abstraction, reliable programming, reuse, and self-documentation
- Early and continuous insight into performance issues through demonstration-based evaluations

TABLE 3-5. General quality improvements with a modern process

QUALITY DRIVER	CONVENTIONAL PROCESS	MODERN ITERATIVE PROCESSES
Requirements misunderstanding	Discovered late	Resolved early
Development risk	Unknown until late	Understood and resolved early
Commercial components	Mostly unavailable	Still a quality driver, but trade-offs must be resolved early in the life cycle
Change management	Late in the life cycle, chaotic and malignant	Early in the life cycle, straightforward and benign
Design errors	Discovered late	Resolved early
Automation	Mostly error-prone manual procedures	Mostly automated, error-free evolution of artifacts
Resource adequacy	Unpredictable	Predictable
Schedules	Overconstrained	Tunable to quality, performance, and technology
Target performance	Paper-based analysis or separate simulation	Executing prototypes, early performance feedback, quantitative understanding
Software process rigor	Document-based	Managed, measured, and tool-supported

Conventional development processes stressed early sizing and timing estimates of computer program resource utilization. However, the typical chronology of events in performance assessment was as follows

- Project inception. The proposed design was asserted to be low risk with adequate performance margin.
- Initial design review. Optimistic assessments of adequate design margin were based mostly on paper analysis or rough simulation of the critical threads. In most cases, the actual application algorithms and database sizes were fairly well understood.
- Mid-life-cycle design review. The assessments started whittling away at the margin, as early benchmarks and initial tests began exposing the optimism inherent in earlier estimates.
- Integration and test. Serious performance problems were uncovered, necessitating fundamental changes in the architecture. The underlying infrastructure was usually the scapegoat, but the real culprit was immature use of the infrastructure, immature architectural solutions, or poorly understood early design trade-offs.

3.6 PEER INSPECTIONS: A PRAGMATIC VIEW

Peer inspections are frequently over hyped as the key aspect of a quality system. In my experience, peer reviews are valuable as secondary mechanisms, but they are rarely significant contributors to quality compared with the following primary quality mechanisms and indicators, which should be emphasized in the management process:

- Transitioning engineering information from one artifact set to another, thereby assessing the consistency, feasibility, understandability, and technology constraints inherent in the engineering artifacts
- Major milestone demonstrations that force the artifacts to be assessed against tangible criteria in the context of relevant use cases
- Environment tools (compilers, debuggers, analyzers, automated test suites) that ensure

representation rigor, consistency, completeness, and change control

- Life-cycle testing for detailed insight into critical trade-offs, acceptance criteria, and requirements compliance
- Change management metrics for objective insight into multiple-perspective change trends and convergence or divergence from quality and progress goals

Inspections are also a good vehicle for holding authors accountable for quality products. All authors of software and documentation should have their products scrutinized as a natural by-product of the process. Therefore, the coverage of inspections should be across all authors rather than across all components.

4. THE OLD WAY AND THE NEW

4.1 THE PRINCIPLES OF CONVENTIONAL SOFTWARE ENGINEERING

1. **Make quality #1.** Quality must be quantified and mechanisms put into place to motivate its achievement
2. **High-quality software is possible.** Techniques that have been demonstrated to increase quality include involving the customer, prototyping, simplifying design, conducting inspections, and hiring the best people
3. **Give products to customers early.** No matter how hard you try to learn users' needs during the requirements phase, the most effective way to determine real needs is to give users a product and let them play with it
4. **Determine the problem before writing the requirements.** When faced with what they believe is a problem, most engineers rush to offer a solution. Before you try to solve a problem, be sure to explore all the alternatives and don't be blinded by the obvious solution
5. **Evaluate design alternatives.** After the requirements are agreed upon, you must examine a variety of architectures and algorithms. You certainly do not want to use "architecture" simply because it was used in the requirements specification.
6. **Use an appropriate process model.** Each project must select a process that makes the most sense for that project on the basis of corporate culture, willingness to take risks, application area, volatility of requirements, and the extent to which requirements are well understood.
7. **Use different languages for different phases.** Our industry's eternal thirst for simple solutions to complex problems has driven many to declare that the best development method is one that uses the same notation throughout the life cycle.
8. **Minimize intellectual distance.** To minimize intellectual distance, the software's structure should be as close as possible to the real-world structure
9. **Put techniques before tools.** An undisciplined software engineer with a tool becomes a dangerous, undisciplined software engineer
10. **Get it right before you make it faster.** It is far easier to make a working program run faster than it is to make a fast program work. Don't worry about optimization during initial coding
11. **Inspect code.** Inspecting the detailed design and code is a much better way to find errors than testing
12. **Good management is more important than good technology.** Good management motivates people to do their best, but there are no universal "right" styles of management.
13. **People are the key to success.** Highly skilled people with appropriate experience, talent, and training are key.
14. **Follow with care.** Just because everybody is doing something does not make it right for you. It may be right, but you must carefully assess its applicability to your environment.
15. **Take responsibility.** When a bridge collapses we ask, "What did the engineers do wrong?" Even when software fails, we rarely ask this. The fact is that in any engineering discipline, the best methods can be used to produce awful designs, and the most antiquated methods to produce elegant designs.
16. **Understand the customer's priorities.** It is possible the customer would tolerate 90% of the functionality delivered late if they could have 10% of it on time.
17. **The more they see, the more they need.** The more functionality (or performance) you provide a user, the more functionality (or performance) the user wants.
18. **Plan to throw one away.** One of the most important critical success factors is whether or not a product is entirely new. Such brand-new applications, architectures, interfaces, or algorithms rarely work the first

time.

19. **Design for change.** The architectures, components, and specification techniques you use must accommodate change.
20. **Design without documentation is not design.** I have often heard software engineers say, "I have finished the design. All that is left is the documentation. "
21. **Use tools, but be realistic.** Software tools make their users more efficient.
22. **Avoid tricks.** Many programmers love to create programs with tricks constructs that perform a function correctly, but in an obscure way. Show the world how smart you are by avoiding tricky code
23. **Encapsulate.** Information-hiding is a simple, proven concept that results in software that is easier to test and much easier to maintain.
24. **Use coupling and cohesion.** Coupling and cohesion are the best ways to measure software's inherent maintainability and adaptability
25. **Use the McCabe complexity measure.** Although there are many metrics available to report the inherent complexity of software, none is as intuitive and easy to use as Tom McCabe's
26. **Don't test your own software.** Software developers should never be the primary testers of their own software.
27. **Analyze causes for errors.** It is far more cost-effective to reduce the effect of an error by preventing it than it is to find and fix it. One way to do this is to analyze the causes of errors as they are detected
28. **Realize that software's entropy increases.** Any software system that undergoes continuous change will grow in complexity and will become more and more disorganized
29. **People and time are not interchangeable.** Measuring a project solely by person-months makes little sense
30. **Expect excellence.** Your employees will do much better if you have high expectations for them.

4.2 THE PRINCIPLES OF MODERN SOFTWARE MANAGEMENT

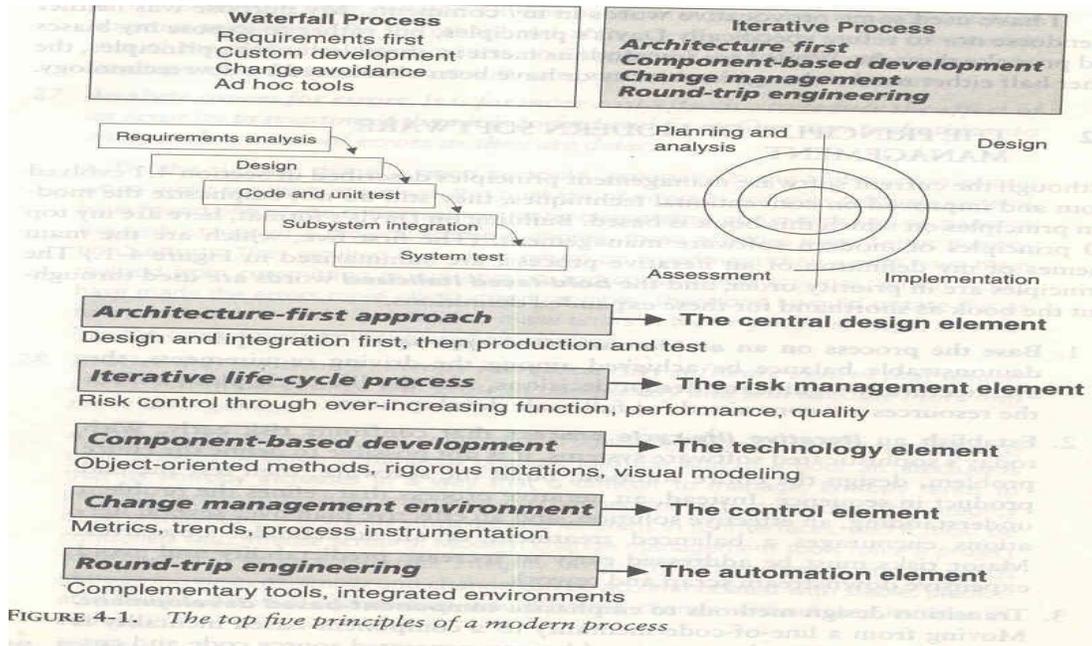
Top 10 principles of modern software management are. (The first five, which are the main themes of my definition of an iterative process, are summarized in Figure 4-1.)

Base the process on an *architecture-first approach*. This requires that a demonstrable balance be achieved among the driving requirements, the architecturally significant design decisions, and the life-cycle plans before the resources are committed for full-scale development.

Establish an *iterative life-cycle process that confronts risk early*. With today's sophisticated software systems, it is not possible to define the entire problem, design the entire solution, build the software, and then test the end product in sequence. Instead, an iterative process that refines the problem understanding, an effective solution, and an effective plan over several iterations encourages a balanced treatment of all stakeholder objectives. Major risks must be addressed early to increase predictability and avoid expensive downstream scrap and rework.

Transition design methods to emphasize *component-based development*. Moving from a line-of-code mentality to a component-based mentality is necessary to reduce the amount of human-generated source code and custom development.

4. **Establish a *change management environment*.** The dynamics of iterative development, including concurrent workflows by different teams working on shared artifacts, necessitates objectively controlled baselines.



5. **Enhance change freedom through tools that support round-trip engineering.** Round-trip engineering is the environment support necessary to automate and synchronize engineering information in different formats (such as requirements specifications, design models, source code, executable code, test cases).
6. **Capture design artifacts in rigorous, model-based notation.** A model based approach (such as UML) supports the evolution of semantically rich graphical and textual design notations.
7. **Instrument the process for objective quality control and progress assessment.** Life-cycle assessment of the progress and the quality of all intermediate products must be integrated into the process.
8. **Use a demonstration-based approach to assess intermediate artifacts.**
9. **Plan intermediate releases in groups of usage scenarios with evolving levels of detail.** It is essential that the software management process drive toward early and continuous demonstrations within the operational context of the system, namely its use cases.
10. **Establish a configurable process that is economically scalable.** No single process is suitable for all software developments.

Table 4-1 maps top 10 risks of the conventional process to the key attributes and principles of a modern process

TABLE 4-1. Modern process approaches for solving conventional problems

CONVENTIONAL PROCESS: TOP 10 RISKS	IMPACT	MODERN PROCESS: INHERENT RISK RESOLUTION FEATURES
1. Late breakage and excessive scrap/rework	Quality, cost, schedule	Architecture-first approach Iterative development Automated change management Risk-confronting process
2. Attrition of key personnel	Quality, cost, schedule	Successful, early iterations Trustworthy management and planning
3. Inadequate development resources	Cost, schedule	Environments as first-class artifacts of the process Industrial-strength, integrated environments Model-based engineering artifacts Round-trip engineering
4. Adversarial stakeholders	Cost, schedule	Demonstration-based review Use-case-oriented requirements/testing
5. Necessary technology insertion	Cost, schedule	Architecture-first approach Component-based development
6. Requirements creep	Cost, schedule	Iterative development Use case modeling Demonstration-based review
7. Analysis paralysis	Schedule	Demonstration-based review Use-case-oriented requirements/testing
8. Inadequate performance	Quality	Demonstration-based performance assessment Early architecture performance feedback
9. Overemphasis on artifacts	Schedule	Demonstration-based assessment Objective quality control
10. Inadequate function	Quality	Iterative development Early prototypes, incremental releases

4.3 TRANSITIONING TO AN ITERATIVE PROCESS

Modern software development processes have moved away from the conventional waterfall model, in which each stage of the development process is dependent on completion of the previous stage.

The economic benefits inherent in transitioning from the conventional waterfall model to an iterative development process are significant but difficult to quantify. As one benchmark of the expected economic impact of process improvement, consider the process exponent parameters of the COCOMO II model. (Appendix B provides more detail on the COCOMO model) This exponent can range from 1.01 (virtually no diseconomy of scale) to 1.26 (significant diseconomy of scale). The parameters that govern the value of the process exponent are application precedentedness, process flexibility, architecture risk resolution, team cohesion, and software process maturity.

The following paragraphs map the process exponent parameters of COCOMO II to my top 10 principles of a modern process.

- **Application precedentedness.** Domain experience is a critical factor in understanding how to plan and execute a software development project. For unprecedented systems, one of the key goals is to confront risks and establish early precedents, even if they are incomplete or experimental. This is one of the primary reasons that the software industry has moved to an *iterative life-cycle process*. Early iterations in the life cycle establish precedents from which the product, the process, and the plans can be elaborated in *evolving levels of detail*.
- **Process flexibility.** Development of modern software is characterized by such a broad solution space and so many interrelated concerns that there is a paramount need for continuous incorporation of changes. These changes may be inherent in the problem understanding, the solution space, or the plans. Project artifacts must be supported by efficient *change management* commensurate with project needs. A *configurable process* that allows a common framework to be adapted across a range of projects is necessary to achieve a software return on investment.
- **Architecture risk resolution.** *Architecture-first* development is a crucial theme underlying a successful iterative development process. A project team develops and stabilizes architecture before

developing all the components that make up the entire suite of applications components. An **architecture-first** and **component-based development approach** forces the infrastructure, common mechanisms, and control mechanisms to be elaborated early in the life cycle and drives all component make/buy decisions into the architecture process.

- **Team cohesion.** Successful teams are cohesive, and cohesive teams are successful. Successful teams and cohesive teams share common objectives and priorities. Advances in technology (such as programming languages, UML, and visual modeling) have enabled more rigorous and understandable notations for communicating software engineering information, particularly in the requirements and design artifacts that previously were ad hoc and based completely on paper exchange. These **model-based** formats have also enabled the **round-trip engineering** support needed to establish change freedom sufficient for evolving design representations.
- **Software process maturity.** The Software Engineering Institute's Capability Maturity Model (CMM) is a well-accepted benchmark for software process assessment. One of key themes is that truly mature processes are enabled through an integrated environment that provides the appropriate level of automation to instrument the process for **objective quality control**.

Important questions

1.	<i>Explain briefly Waterfall model. Also explain Conventional s/w management performance?</i>
2.	<i>Define Software Economics. Also explain Pragmatic s/w cost estimation?</i>
3.	<i>Explain Important trends in improving Software economics?</i>
4.	<i>Explain five staffing principal offered by Boehm. Also explain Peer Inspections?</i>
5..	<i>Explain principles of conventional software engineering?</i>
6.	<i>Explain briefly principles of modern software management</i>